Air Force Rocket Propulsion Laboratory
(Air Force Research Laboratory)
Edwards Air Force Base
On Leuhman Ridge near Junction
of Highways 58 and 395
Boron Vicinity
Kern County
California

HAER No. CA-236

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
San Francisco, California

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HISTORIC AMERICAN ENGINEERING RECORD
EDWARDS AIR FORCE BASE,
AIR FORCE ROCKET PROPULSION LABORATORY

(AIR FORCE RESEARCH LABORATORY)

HAER No. CA-236

Location: On Leuhman Ridge in the northeastern portion of Edwards Air Force Base (AFB), near the junction of Highway 58 and Highway 395 in Kern and San Bernardino Counties, California.

Date of Construction: 1948-1967.

Present Owner: U.S. Air Force, AFFTC, Edwards AFB, California.

Present Occupants: U.S. Air Force, Air Force Research Laboratory (AFRL), Propulsion Directorate.

Present Use: Research laboratory for rocket propulsion.

Significance: Since its inception, the AFRL has been devoted to the advancement of rocket technology in support of U.S. military weapons and space flight superiority. Unlike any other facility associated with rocket systems research, design, testing, and evaluation (RDT&E), the AFRL provided facilities for all aspects of systems development and supported some aspect of the evolution of each of the significant rocket and missile systems developed between the Cold War era and the present.

Test Area 1-100 played an exceptionally important role in the development of the Minuteman missile program and in the RDT&E of performing "hot-firings" from underground missile silos. Air Force engineers at the AFRL developed the technology for achieving a successful hot-firing and designed the first silo facility in the United States that could perform this function. The ability to hot-fire the Minuteman missile was one of its most influential features because it reduced the launch time to 30 minutes or less, which put the United States on par with Soviet launch capabilities.

Test Area 1-115 was the first testing facility constructed at the AFRL and was exceptionally important in the advancement of both Air Force and contractor testing and evaluation of four nationally significant missile programs and generations of intermediate rocket programs. Early tests at Test Area 1-115 of the rocket-assisted takeoff (RATO) system reflect the AFRL's early association with the Air Force Flight Test Center, whereas later tests of the Atlas, Thor, Titan, and Bomarc programs illustrate the AFRL's exceptionally important role in the advancement of the U.S. Cold War race for technological superiority.

Test Area 1-125 is a unique facility at the AFRL because it originally was built for and by the National Aeronautics and Space Administration (NASA) as the F-1 production test facility. Although NASA had other testing facilities across the United States, the ability to construct three test stands capable of testing engines with 2 million pounds of thrust and use the RDT&E facilities of the AFRL proved to be a valuable asset to the success of the Apollo/Saturn V program.

Test Area 1-120 provided the Air Force and industry with testing facilities that played an exceptionally important role in the advancement of nationally significant missile and space programs. Test Stand 1-A originally was constructed to accommodate a fully assembled Atlas intercontinental ballistic missile (ICBM). It supported that program until an accident damaged the stand's superstructure. After the launch of Sputnik and the ensuing focus on the Apollo Saturn V program, new construction and existing facilities were turned over to NASA and Rocketdyne to perfect the E-1 and F-1 engines. The superstructure of Test Stand 1-A was rebuilt to accommodate the Rocketdyne F-1 engine, which eventually propelled the Saturn V lunar rocket.

PART I. PHYSICAL CONTEXT OF THE SITE

The Air Force Research Laboratory (AFRL) encompasses approximately 65 square miles, or 13 percent of the approximately 470 square miles that make up Edwards Air Force Base (AFB). The base is located in the Antelope Valley, in the western Mojave Desert, north of Los Angeles, California. The valley is relatively flat and is bordered by the Tehachapi Mountains on the northwest and the San Gabriel Mountains on the south. The vegetation in this area is creosote bush scrub, which is characterized by creosote bush, sagebrush, Joshua trees, and other desert flora.

The AFRL is situated in the eastern portion of Edwards AFB. Most of the built environment at the AFRL is concentrated on and directly east of Leuhman Ridge. The ridge, which runs northeast to southwest, is approximately 2 miles east of the eastern shore of Rogers Dry Lake. The landscape is characterized by both dramatic and gradual changes in elevation. The western face of Leuhman Ridge, which rises more than 350 feet above the valley floor, undulates with a series of natural washes and promontories. The eastern face of the ridge rolls more gradually in its descent to the valley floor, with a natural shelf immediately west of the ridgeline. The other major topographical feature is Haystack Butte, located southeast of Leuhman Ridge. This dual-peaked butte rises more than 250 feet in a one-half-square-mile area.

Prominent natural features define the AFRL's layout and transportation patterns. The basic arrangement consists of the northeast/southwest ridgeline above the natural shelf with three long roads radiating north and east from the central shelf. The land use patterns at the AFRL also follow this layout. The large, high-capacity test stands are located along the ridge, which allows the natural washes to act as flumes for the test stands (CA-236-4). The administrative, support, and general laboratory facilities are centrally located on the natural shelf west of the ridge. Finally, testing and research areas are located along both Mercury and Mars Boulevards, separated by open spaces to ensure both safety and security.

PART II. HISTORICAL CONTEXT

Roots of Rocket Propulsion Research and Development at Edwards AFB

Rocket propulsion research at Edwards AFB began in 1941, when scientists from the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT) began testing its jet-assisted takeoff rockets at the Muroc Lake Bombing and Gunnery Range. For this project, which came under the control of the Army Air Corps in 1940 and was renamed Jet Propulsion Laboratory Edwards Test Station in 1944, ground-breaking work was conducted on the development and testing of solid propellant rockets to assist with aircraft takeoffs (Computer

Sciences Corporation 1995). During World War II, flight testing was conducted for America's first jet bomber (XB-43), rocket-powered aircraft (MX-324), and jet fighter (XP-59) at Muroc Flight Test Base, located north of the bombing and gunnery range (Neufeld 1990; Computer Sciences Corporation 1995). In direct support of Muroc Army Air Field and its later incarnation as the Air Force Flight Test Center (AFFTC), rocket-propelled sleds were used for deceleration testing at the North Base Test Track in the 1940s and 1950s and to test vehicle components, seat ejection systems, and other systems at the South Base High Speed Test Track from 1948 through 1962.

<u>Roots of Rocket Propulsion Research and Development on Leuhman Ridge</u>

In 1946, Consolidated-Vultee Aircraft Corporation (Convair) initiated the Atlas program although no testing facilities capable of accommodating the development of the missile's propulsion systems existed at the time (Goethert and Lennert 1962). This program was the primary impetus for selecting a site for a static test facility in an area less densely populated than Wright Field. Situated near Dayton, Ohio, Wright Field was the location of the primary rocket research facility (the Power Plant Laboratory) for the military at the time. A committee from the Power Plant Laboratory at Wright Field visited Muroc Army Airfield and chose Leuhman Ridge as the site for such a testing facility.

The site had many advantages, including being located close to Muroc Army Airfield's large runway, which could handle freight of any size, and to Muroc Flight Test Base with its jet aircraft testing facilities and its power plant branch with rocket and rocket propulsion sections. Also nearby were Caltech's Jet Propulsion Laboratory field location test stands, located on the Muroc facility, and major defense manufacturers in the Los Angeles area (Markusen et al. 1991; Lotchin 1992; U.S. Air Force 1950a, 1950b, 1950c). An additional advantage of the location was its remoteness. The remote location was necessary not only for security and safety precautions, but also because of the potential for noise nuisance, potential for violent explosions, and the toxic nature of the propellant. The desert environment was advantageous in terms of maintenance, resulting in no rust and little deterioration of expensive test stands and facilities (Robert Corley, personal communication 1998). Finally, the location of Leuhman Ridge on federally owned land precluded the need for lengthy land acquisition processes (Schmidt and Dynes 1951).

Because of the tremendous cost to private industry, power plant personnel concluded that a government-operated, centralized test facility was the best approach for meeting these new testing needs. In addition, the military believed that a testing station built at a contractor's plant would give that firm almost exclusive rights to future contracts for high-thrust propulsion systems or would require additional expenditures for similar facilities elsewhere (U.S. Air Force 1954a; Schmidt and Dynes 1951).

Approach to Research and Development at Leuhman Ridge

The focus of the Experimental Rocket Engine Test Station (ERETS) on Leuhman Ridge was missile systems of great size and technical complexity, including intercontinental ballistic missiles (ICBMs) and intermediate range ballistic missiles (IRBMs), that required expensive facilities for extensive research, testing, and evaluation. Testing abilities ranged from individual component testing to captive engine and motor firings to captive testing of fully assembled vehicles. Testing at all stages of development saved time and money and yielded more data with each test. A primary feature distinguishing Air Force missile research, design, testing, and evaluation (RDT&E) performed at Leuhman Ridge from other RDT&E was the concurrent testing of all the necessary equipment, systems, and procedures required to produce and deploy a weapon system. The rocket, missile, ground support equipment, and launch complex were designed and produced simultaneously. This practice, known as "concurrency", also involved simultaneous building of multiple generations of weapons systems.

Concurrent and phased RDT&E represented an important divergence from tradition. In the past, American scientists had researched one generation of a system, developed its design, deployed it, and moved on to the next generation (Divine 1993; Stine 1991). This approach continued at the National Aeronautics and Space Administration (NASA) and industry facilities during this period because these institutions typically were dedicated to the success of a single program and objective. The Air Force was unique in offering a single laboratory that could support multiple testing programs for industry, military, and NASA users, as well as ongoing research and development of the "building blocks of rocket technology" for use by future Air Force programs (William Lawrence, personal communication 1998).

Although concurrency offered the advantage of providing the largest number of operational systems in the least amount of time, it had disadvantages. The management task of concurrency was overwhelmingly complex. It involved parallel advances in research, design, testing, and manufacture of vehicles and components; design and construction of test facilities; testing of components and systems; expansion and creation of industrial facilities; and the building of launch sites (Divine 1993; Stine 1991). Concurrency required a vast expenditure of resources because of the sheer number of programs in development. Frequently, manufacturers worked to finish their production lines as their system prototype was tested. However, in the final analysis, concurrency was responsible for saving time and money that could be channeled into the development of new weapons systems. In addition, testing components saved money and resources by pinpointing problems and solving them before they jeopardized entire systems.

Western Development Division and the ICBM (1953–1957)

In 1953, ERETS was supporting three major missile programs: the Bomarc F-99 surface-to-air interceptor being developed by Boeing; the Navaho long-range surface-to-surface missile being developed by North American Aviation; and Atlas, the first projected surface-to-surface intercontinental bombardment system, being developed by Convair (U.S. Air Force 1954b:148). In 1953 and 1954, progress was being made on all aspects of guided missile systems (flight vehicle, power plant, guidance system, and warhead) at ERETS. Developments in celestial guidance systems and equipment indicated that the system was feasible for long-range guidance. Solutions to the reentry problem (the warhead would melt before impact) had been proposed. Progress in reducing the size and weight of warheads was being made. (U.S. Air Force 1955a:182.)

In October 1953, the special assistant to the Secretary of the Air Force called on the Air Force to put more time and resources into missile research and appointed prestigious scientists to a committee code-named "Teapot". The objective of the committee was to evaluate Soviet missile development and review all available information about American missile development to determine the feasibility of producing an ICBM as a weapon system. The report produced by the committee concluded that the United States had wasted valuable time between 1945 and 1950 while the three branches of the armed services competed for funding. However, the report concluded, if the government secured the services of talented scientists and engineers, provided adequate funding, and implemented new management techniques, the United States could develop and deploy an effective ICBM before the Soviet Union (Divine 1993; Stine 1991).

In April 1954, President Eisenhower gave approval for acceleration of the ICBM development program. The Air Research and Development Command (ARDC), located at Andrews AFB in Maryland, created the Western Development Division (WDD), headquartered in Inglewood, California. WDD was a development management group whose sole responsibility was to oversee the research and development, testing, and production leading to creation of a successful ICBM. In September 1955, Eisenhower gave ICBM development the highest national priority, and ordinary procedures were dropped, cutting through governmental red tape, to accelerate the program (Levine 1994:34–35). As a result of this national focus, ERETS was renamed the Rocket Engine Test Laboratory (RETL), and the construction of the remaining planned facilities took on new importance. RETL was still a part of the AFFTC, reporting to the commander of Edwards AFB and taking technical direction from ARDC through both the Wright Air Development Center and WDD.

Because of the pace of research at the facility, it was challenging for planners to keep up with advances in technology. For the necessary facilities to be in place by the time they were needed, Air Force facility managers had to plan and build for projects that had only recently been conceived (William Lawrence, personal communication 1998). Because of greater requirements for state-of-the-art equipment, facilities, and instrumentation, research programs influenced the perpetual modernization of the rocket propulsion test facilities. For example, Project 3850 was designed to develop equipment and techniques necessary to support the captive missile and rocket tests essential to ICBM development. Aspects of the project included the development of flame deflectors, high-pressure equipment, hazardous propellant equipment, facilities criteria, specialized testing methods and techniques, and high-thrust testing facilities (U.S. Air Force 1957a).

Sputnik and the Reaction of the West

U.S. morale was dealt a major blow in October 1957, when the Soviet Union launched Sputnik. The launch of Sputnik was not only an indication that the USSR had pulled ahead in the space race, but an indication of Soviet weapons development. It became apparent that the Soviet Union had a large, long-range missile at a time when the United States had not yet successfully tested the much smaller Atlas. The launch of Sputnik triggered hysteria in Europe and the United States that marked a unique period in the Cold War. The general belief was that the West faced a technologically superior enemy that might soon enjoy superiority and that the West might actually lose the Cold War, the arms race, and the space race. During other periods, Western fears were focused more narrowly, and the overestimation of the enemy was not so all encompassing. (Levine 1994:57–59.)

The Sputnik launch placed increased emphasis on the need for Air Force launch vehicles to place military satellites into orbit and to be prepared to counter foreign satellites if necessary. Sputnik was the impetus for many changes in government organization dealing with defense, space, and scientific research. These changes included the presidential advisory apparatus, the creation of the Advanced Research Project Agency (ARPA) and NASA, and the eventual reorganization of the Defense Department. This event was also the impetus for the accelerated development of the Discoverer satellite; the Atlas, Thor, and Jupiter projects; and the 500,000-pound-thrust E-1 engine, which would later be scaled up to the 1-million-pound-thrust F-1 engine. In 1958, the Air Force was allowed to proceed with the development of the Minuteman missile. During that year, the AFRL was very active. A coordinator was necessary to make sure that no two stands were firing simultaneously (Robert Corley, personal communication 1998). Because of the acceleration of programs, the streamlining of the organization of the Defense Department, and the increased funding directed toward missile development and space exploration, by 1961, the United States had pulled ahead of the Soviet Union in the arms race and maintained its strategic superiority (Levine 1994:74).

The Sputnik launch was seen as evidence of an impending "missile gap". If the United States failed to catch up, some believed, the Soviet Union could gain first strike capability within a few years. The United States would no longer be insulated from enemy attack by its geographic isolation. This missile gap could become a "deterrent gap", a situation in which the USSR could attack without fear of effective retaliation (Levine 1994:58). Soviet ICBMs took 30 minutes to reach North America; later the missile's flight time was shortened to 15 minutes. It was vital that American missiles be launchable within that time frame to avoid being destroyed in the ground. Research efforts increased to reduce the launch preparation time for American ICBMs by shifting from liquid to solid propellants. Liquid fuels were extremely unstable and had to be loaded just before launch. Solid propellant missiles could be launched almost immediately because the fuel was self-contained and storable (Heppenheimer 1997; Lee Meyer, personal communication 1998). Development of the ability to hot-fire these solid propellant missiles was developed by the United States and greatly contributed to achieving the goal of a 15-minute flight time. (Neufeld 1990; Stine 1991).

In 1959, the Leuhman Ridge facility was expanded to accommodate work on the F-1 engine. In that same year, the engineers and technicians of the Rocket Propulsion Division from Wright-Patterson AFB were transferred to Edwards AFB and incorporated into the Directorate of Missile Captive Tests (DMCT). The mission of the DMCT in 1958 was to

> direct the: research, development, and evaluation required in the performance of Air Force Flight Test Center captive evaluation testing of missile system and their components; accomplishment of technical and logistic support to missile contractors conducting tests at the Air Force Flight Test Center; studies of test methods and facilities needed to accomplish potential future mission responsibilities. (U.S. Air Force 1958:199)

This directorate was renamed the Directorate of Rocket Propulsion and Missiles within the year (U.S. Air Force 1961a, 1964b). The development of the rocket facility on Leuhman Ridge had come full circle. Originally an ancillary part of the ARDC rocket program located at Wright Field's Power Plant in 1952, the facility at Leuhman Ridge had become the Air Force's primary rocket propulsion research and testing facility by 1959. This consolidation enlarged the mission to include the development of rocket propulsion technology for air-launch ballistic missile and space applications.

The Space Race

Although the United States had pulled ahead of the Soviet Union in the arms race by 1961, the Soviets were generally considered to be far ahead of the Americans in the space race. The Americans had accomplished several "firsts" and had made important scientific and technological advances. American research had detected the Van Allen belts and solar X-rays; introduced solar cells and made the first television pictures of Earth; launched the first weather, communications, and polar-orbit satellites; and made the first recovery from orbit. But the Soviet "firsts" were more spectacular. The Soviets had launched the first satellite, were the first to reach escape velocity, were the first to "hit" the moon (with a probe), were the first to see the far side of the moon, and were the first to send animals into orbit and return them safely to earth. And in April 1961, the Soviets were the first to launch a man into Earth orbit (Levine 1994:117).

This event, in combination with a shaky political situation resulting from such events as the Bay of Pigs, inspired President Kennedy to strive for a dramatic achievement. Vice President Johnson conferred with NASA leaders, who made a bold suggestion. They believed that the American space program could put a man on the moon by 1967 or 1968, ahead of the Soviets. Eager to upstage the Soviets in the space race, President Kennedy declared on May 25, 1961, "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to earth" (Levine 1994).

A plan for the Apollo project to land a man on the moon was in place by the end of 1962. The mission plan called for a manned lunar module to detach from the spacecraft, land on the moon, and return to the spacecraft orbiting the moon. The astronauts would return to Earth in the spacecraft, and the lunar module would be left orbiting the moon. This technological feat would entail two liftoffs (one from Earth and one from the moon), escapes from the gravitational fields of Earth and the moon, and a soft landing on the surface of the moon. Fortunately, research and development of some of the critical components, such as the F-1 engine, the J-2 engine, and the Saturn VIB stage, was already underway. Testing continued and necessitated new facilities capable of testing large engines and testing in simulated space conditions.

At the same time, the United States continued to pursue its Mercury and Gemini manned orbiter projects and Ranger and Mariner interplanetary probe projects. It was during the Gemini series that the United States, using the Saturn and Centaur launch vehicles, "caught up" to the Soviet Union in the ability to put heavy loads into space. In addition, the United States' Surveyor series made important discoveries about the moon. Although they occurred too late to contribute to the Apollo design, they confirmed that the design was reasonably safe. (Levine 1994.)

In 1960, the Directorate of Rocket Propulsion and Missiles was reorganized and renamed the Directorate of Rocket Propulsion (U.S. Air Force 1960). No jobs were created or eliminated, but the directorate's new mission emphasized propulsion development instead of the previously emphasized areas of missile systems testing, propulsion development, and component reliability testing. In 1961, the Directorate of Rocket Propulsion, although it was still working in the field of rocket propulsion (most notably the Minuteman program), was reassigned to the Space Systems Division. In 1962, the name was changed again, this time to the Air Force Rocket Propulsion Laboratory (AFRPL), a change that reflected the expanded role in conducting and directing rocket propulsion research. At the same time, the Leuhman Ridge facility was elevated to the status of a

Research and Technology Division Laboratory. In 1967, the Research and Technology Division Laboratory was renamed the Directorate of Laboratories (*Aerotech News and Review* 1990).

Continuing Research at the Rocket Propulsion Facility

The development of the Peacekeeper ballistic missile and the Small ICBM was a major focus of the propulsion facility during the 1970s. The AFRPL, in conjunction with Pratt & Whitney personnel, was involved in the design and advanced development testing of the XLR-129 liquid rocket engine, the high-performance reusable LO2/LH2 rocket engine that was the basis for the main engines of NASA's space shuttle (Willliam Lawrence, personal communication 1996). Because of reports from the Vietnam War that the enemy could visually detect the smoke from burning propellant and thus avoid missile attack, propellant research in the 1970s and 1980s focused on developing new propellants, including smokeless and cleaner burning solid propellants (U.S. Air Force 1984a), as well as solar and electric propulsion (U.S. Air Force 1984b, 1985, 1986).

In the mid-1980s, the basic mission of the rocket propulsion laboratory was expanded to include responsibility for developing additional satellite systems and space technology programs. The development of heavy lift vehicles and kinetic energy weapons in support of the Strategic Defense Initiative program was among these new responsibilities. Reflecting this change in mission was a change in name. The AFRPL was renamed the Air Force Astronautics Laboratory. The Titan 34D Solid Rocket Booster was tested on test stands in Test Area 1-125 that were constructed for the development of the F-1 engine. These boosters were used to launch U.S. spy, early warning, and communications satellites (*Antelope Valley Press* 1987; General Physics Corporation 1992). Test stands and superstructures in Test Area 1-115 went from standby status during most of the 1970s to being abandoned and having the steel components scrapped during the early 1980s or mid-1980s (William Lawrence, personal communication 1998).

In 1990, the Air Force Astronautics Laboratory was renamed Phillips Laboratory, Propulsion Directorate. This change reflected the consolidation of Air Force laboratories across the nation into four "superlabs". The AFRL's work in the 1990s has included technology development for space launch vehicles, space power and structures, and propellant and combustion research. Important projects include the Titan IV Solid Rocket Booster, which is being tested on revamped Test Stands 1-C, and 1-D in Test Area 1-125; the high energy density materials project, focused on creating new fuels; efforts to develop space-based interceptors for theater missile defense; work on the next generation of launch systems, including the X-33, the X-34, the evolved expendable launch vehicle; and the miniature sensor technology integration program, which involves developing a low-cost small spacecraft to detect and track ballistic missiles (U.S. Air Force 1995).

In 1997, the name of the Phillips Laboratory was changed to the Air Force Research Laboratory. The AFRL combines all four superlabs and the Air Force Office of Scientific Research into a single laboratory commanded from Wright-Patterson AFB in Ohio. The rocket group at Edwards AFB covers ballistic launch, spacelift, tactical, and spacecraft propulsion research and development (Edwards Air Force Base 1997). Although in its early years the facility and its staff were dedicated to developing Cold War ballistic missiles and satellite systems and winning the space race, the decade of the 1990s has seen a marked transition to broadening the dual-use application of propulsion technology for commercial launch and satellite systems through participation with virtually all U.S. aerospace corporations (Tetra Tech 1997:2-31).

Construction History

Early Construction. After the decision to build the facility had been made, contractors experienced with rocket engine development were solicited for the proposed test station design plan. These contractors included Curtiss-Wright Corporation; North American Aviation; N. W. Kellogg Company; Reaction Motors; and Aerojet Engineering Corporation (AEC), a subsidiary of Aerojet General Corporation, which had been formed earlier by GALCIT scientists. Because the type of large-scale static test stand required for the test facility had no precedent, the use of an engineering subsidiary of a rocket manufacturer promised the best possible results for construction of the test facilities (Tetra Tech 1997).

In 1947, the Air Materiel Command, through its Rocket Branch, and the U.S. Army Corps of Engineers (Corps) contracted with AEC for the design of the rocket engine test stands and auxiliary facilities at Muroc Army Airfield (U.S. Army Air Force 1948; U.S. Air Force 1964a). AEC was the logical choice to advise the Corps. Since Aerojet's inception as a spinoff of GALCIT, it had concentrated on rocket research and development, whereas competing contractors at the time were multidisciplinary organizations and aircraft manufacturers.

In 1952, ERETS was activated. Its primary mission was "to accomplish research, development, and static testing of experimental and production rocket power plants, and to provide authorized contractors and other Governmental agencies with facilities and engineering assistance in research, development, and testing of experimental rocket power plants" (U.S. Air Force 1953:474). Rocket Branch personnel performed liquid rocket propellant servicing operations for aircraft and provided engineering and consulting services to AFFTC activities using rocket engines and their components (U.S. Air Force 1953:474).

In the late 1940s, the largest rocket engine, or power plant, in existence had a thrust of 75,000 pounds. Construction of two test stands rated at 400,000 pounds of thrust was thought to provide a more than adequate margin to accommodate improvements in technology (U.S. Air Force

1964b). The test stands and control station, located in Test Area 1-115, were activated early in 1953. In 1952, while the first stage of construction was being completed at the facility, work was initiated in Test Area 1-110 on additional test stands to be operational by 1956 (U.S. Air Force 1964b).

Initial Building Campaign (1948–1953). The Corps was responsible for constructing the infrastructure and the nontechnical facilities, and Aerojet was charged with designing and constructing the technical facilities at the new rocket test location.

Construction of the infrastructure began in summer 1947. The Corps initiated its nontechnical facilities construction in November 1949 although the infrastructure was not complete. Service buildings of lightweight, reinforced concrete or of structural steel with corrugated roofs and side panels were designed and erected. Buildings followed the design standards outlined in the Corps' Manual for Military Construction except for features unique to the desert environment or for the large rocket engine test facility (William Lawrence, personal communication 1998). Some of the exceptions included the provisions for seismic loading, wind loading, concrete design, maximum earth-bearing pressure, and vibrations absorbed by the foundation (Schmidt and Dynes 1951).

In February 1950, Aerojet initiated construction of the technical facilities on Leuhman Ridge. The site's initial construction was scheduled to be completed in 1952 by Aerojet. The initial facilities designed for the site were (U.S. Air Force 1954b, 1964a):

- two test stands (Test Stands 1-3 [Bldg. 8698] and 1-5 [Bldg. 8641]), each thrust-rated at 400,000 pounds;
- control station structure (1-7 [Bldg. 8668]);
- 14,200-gallon nitric acid storage;
- nitrogen cascade system;
- intermediate fuel storage;
- general machine shop;
- assembly area;
- test stand machine shop;
- fire station;

- cafeteria to seat 80 persons;
- bachelor officers' quarters (for 34 men);
- administration building;
- vehicle maintenance shop;
- storage warehouses;
- area maintenance shop; and
- propellant facilities.

Between 1949 and the end of 1952, $5 million had been spent on building the original facilities on Leuhman Ridge (U.S. Air Force 1964a). In 1952, Aerojet completed its initial phase of construction, and the facility was ready to assume its mission to provide testing facilities for all the Air Force's important missile and rocket projects. During this initial building phase, the infrastructure at the rocket lab and much of the facilities known as CE (Civil Engineering), Test Area 2-10, Test Area 2-20, and Test Area 1-115 were constructed (CA-236-6). Of the facilities listed above, the test stands, control station structure, and related testing facilities were constructed in Test Area 1-115; the vehicle maintenance, storage, and area maintenance shops were built in Test Area 2-20; and CE, the administration building, the cafeteria, and the bachelor officers' quarters were built in Test Area 2-10. The use of "1-" before the number of an area indicates a high-hazard area, whereas the "2-" indicates a minimal hazard area (William Lawrence, personal communication 1998).

Second Building Campaign (1953–1957). The remaining initial construction included in the master plan was to be finished by 1956 (U.S. Air Force 1954b). The acceleration of the ICBM program made completing the facility an even greater priority. New test areas constructed included Test Areas 1-14, 1-21, 1-110, and 1-120. These areas included Test Stands 1-1 and 1-2 and a control center (1-6) in Test Area 1-110. Other facilities constructed during this period included Test Stand 1-4 and new superstructures on Test Stands 1-3 and 1-5 in Test Area 1-115, a hydrodynamics test building, a 40,000-square-foot missile assembly building, an acid storage facility, a liquid nitrogen facility, a flame deflector water coolant pump facility at Test Stand 1-3, and a 4,000-pounds-per-square-inch (psi) gaseous helium storage and distribution system (U.S. Air Force 1955b, 1957a).

Third Building Campaign (1957–1960). The substantial increase in the need for testing facilities led to construction of test facilities and continued testing of rocket engines and components associated with the development of ICBMs, IRBMs, and the launch vehicle for Saturn V (Bilstein 1980; Divine 1993; Swenson et al. 1966). The expansion that took place in the late 1950s consisted not only of additions to already existing test facilities (Test Areas 1-30 and 1-14) and support areas (Test Area 2-10), but the addition of a motor components test area (Test Area 1-32) and a silo area (Test Area 1-100). In preparation of the influx of personnel, the bachelor officers' quarters were converted to offices for the Air Force and civilian engineers conducting and managing the testing and research programs. On arriving with the transfer group from Wright-Patterson AFB, Mr. Geisler found a Bible on his table and a "No Smoking in Bed" sign in his office, evidence of the building's original purpose (Robert Geisler, personal communication 1998).

Fourth Building Campaign (1961–1967). Construction at the AFRPL in the early 1960s and mid-1960s supported the effort to land on the moon, as well as the ongoing satellite and probe projects. Facilities were created or modified to accommodate large rocket motors and engines and their components and to test engine components and designs in simulated space environments. Modifications and additions were made to Test Areas 1-14, 1-30, 1-32, 1-46, 1-60, 1-110, 1-115, 1-120, and 1-125. By 1967, the AFRPL appeared essentially as we see it today. When necessary, structures and buildings have been constructed since then, as is characteristic of a research facility, but there have been no additional periods of intensive construction.

In 1961, NASA requested the construction of three high-thrust static test stands to broaden its testing capabilities to expand the Apollo program testing conducted on the stands in Test Area 1-120. Three stands and associated facilities were constructed in the new Test Area 1-125. These stands were transferred back to Air Force control in the 1970s.

PART III. HISTORY OF INDIVIDUAL TEST AREAS

Test Area 1-100

The facilities in Test Area 1-100 were constructed by the Air Force expressly for the purpose of conducting tethered launches of the Minuteman missile. Air Force engineers at the AFRL developed the technology for achieving a successful hot-firing and designed the first silo facility in the United States that could perform this function. The ability to hot-fire the Minuteman missile was one of its most influential features because it reduced the launch time to 30 minutes or less, which put the United States on par with Soviet launch capabilities.

Full-scale Minuteman testing was initiated by Boeing in May 1959, and the first launch took place in September of the same year (U.S. Air Force 1960). In the 1970s, Test Area 1-100 was also the site of the first tethered launch of the pre-Peacekeeper missile and played an important role in the development of that system (CA-236-5). Test Area 1-100 played an exceptionally important role in the development of the Minuteman missile program and in the RDT&E of performing hot-firings from underground missile silos. RDT&E of other Minuteman systems, such as propellants, motors, and vehicle components, were being conducted throughout the AFRL at modified testing facilities.

Test Area 1-115

The first test stands activated at the Leuhman Ridge site were located in Test Area 1-115 (CA-236-K-7, CA-236-K-8). Test Stand 1-5, the area control building, and support facilities (fuel tanks and pumps) were activated in October 1952 for Aerojet's rocket-assisted takeoff (RATO) system. Test Stand 1-5 was reconfigured in 1953 to accommodate Bomarc testing and again in 1956 to serve the Thor program (U.S. Air Force 1957b, 1957c) (CA-236-10).

Test Stand 1-3 (CA-236-F-2) was activated in March 1953 with the first firing of the Navaho engine. A second test position was added to Test Stand 1-3 in 1954 and used for Atlas testing. Also in 1954, this test stand was used to test Rocketdyne's Thor IRBM propulsion system (U.S. Air Force 1955c, 1955d, 1957b, 1957c, 1960, 1964b). Because of the rapid erosion of the original cement deflector, a flame deflector was installed in 1955.

Test Stand 1-4 was added to the facility in 1955 and activated in August of that year when the first operational Atlas system was pulled from service and tested there. The test stand played an essential role in testing the reliability of the engine on the Atlas missile and was the site of the integration of each Atlas component as it became available for static testing. During the fourth building campaign, Test Stand 1-3 was reconfigured to conduct reliability evaluation tests on the Titan missile.

Test Area 1-115 was the first testing facility constructed at the AFRL and was exceptionally important in the advancement of both Air Force and contractor testing and evaluation of four nationally significant missile programs and generations of intermediate rocket programs (CA-236-8). Early tests of the RATO system at Test Area 1-115 reflect the AFRL's early association with the Air Force Flight Test Center, whereas later tests of the Atlas, Thor, Titan, and Bomarc programs illustrate the AFRL's exceptionally important role in the advancement of the U.S. Cold War race for technological superiority.

Test Area 1-120

The first test program assigned to Test Stand 1-A was the captive test of the Atlas ballistic missile (CA-236-R-25). Project identification for the Atlas ballistic missile tests was MX-1593 (later WS-107A). The purpose of the Atlas missile program test was to develop a complete missile carrier system.

Test Stand 1-A was used for captive testing of the Atlas flight weight system from 1956 through April 1959 (CA-236-11). The stand was used for approximately 700 hot-firings. The propellant used on the Atlas program was LO_2/Kerosene (JP-4, later RP-1) (Biggs 1992) (CA-236-P-1, CA-236-P-2, CA-236-P-3). On March 5, 1957, the first flight weight firing of the Atlas was conducted on Test Stand 1-A to check the compatibility of the engines, airframe, and test facility and to familiarize personnel with the system. Rocket testing during this time was extremely unpredictable and dangerous. Safety precautions implemented at Test Stand 1-A included a "slide for life", consisting of a cable strung from the upper level of the test stand to the ground near the vehicle assembly building. The "slide for life" enabled personnel to quickly evacuate the test stand in case of emergency by "sliding" down the cable while holding onto, and dangling from, a pulley.

The Convair Division of the General Dynamics Corporation had nearly completed tests on the Atlas missile at Test Stand 1-A when the missile malfunctioned and exploded during a test on March 27, 1959 (CA-236-R-23). The test stand was damaged to such an extent that it was impractical to rebuild it for the two tests remaining to complete the Atlas program. The tests were rescheduled to Test Stand 1-1 in Test Area 1-110. No attempt was made to modify Test Stand 1-A after the March 27, 1959 explosion because the cost for repair work was estimated at $500,000. For all practical purposes, static testing of the Atlas missile had been completed when the explosion occurred.

Test Stands 2-A and 1-B were completed in 1960 and 1961, respectively. All three test stands in Test Area 1-120 were activated in 1961 as the new NASA Static Rocket Engine Test Complex. Test Stand 2-A was designed to accommodate F-1 thrust chamber stability and performance testing. The two vertical test positions on Test Stand 1-B were designed to accommodate up to four F-1 engines firing simultaneously in a "stage test configuration", generating a cumulative thrust of 6 million pounds (U.S. Air Force 1961b, 1964b, 1967). Test Stand 1-A was modified to accommodate 1.5 million pounds of thrust (U.S. Air Force 1961b). The test stand was converted from the Atlas missile configuration to the present configuration for static testing of the E-1 and F-1 engines (CA-236-R-24). Development of the E-1 and F-1 engines reflected a shift in priorities for the test area from Cold War ICBMs to manned space flight.

The F-1 engine test program, which was conducted on Test Stand 1-A, was an integral part of the success story of the Apollo program in the United States' early space exploration. The F-1 engine is almost 20 feet long and more than 12 feet across and weighs more than 9 tons. It was designed for and used in a five-engine cluster for the first stage of the giant Saturn V vehicle, which powered the Apollo astronauts to the moon. The first F-1 engine test was conducted on May 25, 1961, on Test Stand 1-A. The F-1 engine was the largest and most reliable rocket engine ever built, with performance, durability, thrust, and operating capabilities meeting or exceeding all expectations.

In December 1968, the Apollo lunar mission began, and on July 20, 1969, the Apollo 11 mission successfully landed a man on the moon. Approximately 700 engine firings were accomplished from activation in 1960 until research and development were completed in 1969.

Test Area 1-125

Test Area 1-125 originally was built by NASA as the F-1 engine production test facility. Although NASA had other testing facilities across the United States, the ability to construct three test stands capable of testing engines with 2 million pounds of thrust and to use the RDT&E facilities of the AFRL proved to be valuable assets to the Apollo/Saturn V program.

NASA returned control of the area to the Air Force in 1974. Since then, the area has been used to test Rocketdyne's H-1 engine, the Titan 34D, the Titan IV, and solid rocket motors. It also has been used for the hover testing of most satellite and missile kinetic kill vehicles. Between 1975 and 1986, the stands were inactive (General Physics Corporation 1992; The Earth Technology Corporation 1993). Additional facilities were added in the late 1980s and early 1990s. The facilities have been in continuous use or on standby status since the facilities were added, and modifications have been consistent with the intended use of the facility as a rocket propulsion testing area.

PART IV. DESCRIPTION OF INDIVIDUAL TEST AREAS

Test Area 1-100

Test Area 1-100 is located at the terminus of the southern branch of Mercury Boulevard (CA-236-12). The vegetation in this area consists largely of creosote bush and sagebrush. Topographically, the test area site is located in a relatively flat valley, directly east of Leuhman Ridge, north of Haystack Butte, and northwest of Kramer Hills. It is a coffin-shaped, flat area that covers approximately 75 acres.

The test area consists of three buildings and two subterranean silos. Bldg. 8950, the missile fixtures storage facility, is located at the northwestern end of the area's access road. Bldg. 8953 and Bldg. 8955 (the control center) are located near the intersection with Mercury Boulevard (CA-236-B-2). Bldgs. 8959 and 8960 are the two missile silos, located at the southeastern end of the area's access road (CA-236-A-2).

Test Area 1-100 was constructed in 1959 to support the Minuteman ICBM program. It consists of a burn pit, two silos (both with tethered test configurations), and associated support facilities. After preliminary development of test procedures, technicians developed a silo flame deflector and a one-third-scale silo launcher in 1958 and 1959 to accommodate tethered launch tests.

Bldg. 8955. Bldg. 8955 is a concrete block structure measuring 40 by 50 feet and 12 feet high (CA-236-B-7). The flat, builtup roof has a steel coping. The interior is dominated by the instrument room, with smaller spaces devoted to a mechanical room, a toilet, storage space, and an office (CA-236-B-4, CA-236-B-5). Fenestration includes double steel doors on the southwest facade, a single door on the northwest facade, and a single door on the northeast facade that leads to an enclosed passageway. The concrete passageway contains a two-flight staircase that leads down to a concrete subterranean firing control room 48 feet below ground (CA-236-B-6). Above ground, the firing control room is protected by a concrete slab (CA-236-B-3). East of the slab is a 3-foot-diameter vertical corrugated metal pipe with a steel ladder that serves as an escape route from the firing control room. The structure and associated structures appear to be in good condition.

Bldg. 8959. Bldg. 8959 is a subterranean missile silo with a circular driveway for access and loading (CA-236-A-3); a 13- by 13-foot concrete block equipment room with a corrugated metal roof sits on the outside edge of the drive (CA-236-A-4, CA-236-A-5). The silo has a radius of 13 feet and a depth of 144 feet (CA-236-A-6, CA-235-A-7). It has a steel liner on the outside face and an 8-inch continuous concrete insert on the interior face. Interior features include an elevator, a platform, and a steel cage with ladder located next to each other. At the center of the silo is an adjustable platform with a steel pipe railing, reminiscent of a crow's nest (CA-236-A-1). Round sockets are located at 30-degree intervals around the circumference of the top of the silo for installing removable handrails. Two parallel steel rails, each 120 feet long, abut the silo and support the "hatch cover", a square metal box that could be positioned above the silo. Because this hatch cover did not provide a water-tight seal over the opening in the silo, a sump pump was located in the bottom 3 feet of the silo pit to remove rainwater.

Although the silos have been deactivated and, according to international treaty, filled with soil, the structural, associational, locational, and contextual integrity remain intact. Bldg. 8959 has been filled with dirt but otherwise should be in fair condition.

Bldg. 8960. Bldg. 8960 is identical in design Bldg. 8959. Unlike Bldg. 8959, however, Bldg. 8960 has not been filled with dirt. It shows signs of habitation by animals, perhaps birds (branches and other materials gathered on the center crow's nest structure). Overall, the silo appears to be in fair condition.

Test Area 1-115

Test Area 1-115 is located midway along Leuhman Ridge, approximately 1 mile from the main administrative complex. It encompasses a trapezoidal area of approximately 40 acres. The northern boundary line is parallel to and just below the crest of the ridge (CA-236-1). The southern boundary line coincides with Altair Street. The eastern and western boundary lines roughly coincide with Mira Road and the road to Test Area 1-40 (CA-236-7, CA-236-9).

This area has three test stands, six primary buildings, and assorted support buildings and structures (CA-236-2, CA-236-3). It is developed in two tiers, with the test stands and associated buildings on the ridge and the liquid oxygen and fuel structures located approximately 30 feet below the ridgeline, on the southern slope (CA-236-J-1 through CA-236-J-3). From west to east along the ridge, the facilities are Bldg. 8641/Test Stand 1-5; Bldg. 8642, the buildup building for Test Stand 1-5; Bldg. 8649/Test Stand 1-4; Bldg. 8665; Bldg. 8668, the control center for the area; Bldg. 8698/Test Stand 1-3; Bldg. 8680, an electrical substation; and Bldg. 8694, the buildup building for Test Stand 1-3. Test Stands 1-3 and 1-5 were built from the same plans (CA-236-K-9 through CA-236-K-16). Below the ridge, along Altair Street, sit numerous structures related to liquid propellent storage and transmission. Bldg. 8663 is one of the remaining buildings in this area.

Although the area was deactivated and the superstructures of the test stands removed in the 1980s, the area retains its integrity of association, design, context, and materials and its overall ability to convey its history as a significant rocket testing facility.

Bldg. 8698, Test Stand 1-3. The existing structural base of Test Stand 1-3 is a reinforced, poured concrete structure stepped against the northern side of Leuhman Ridge (CA-236-F-1 and CA-236-F-3 through CA-236-F-6). The overall measurements of the base, including the terminal roof deck, the valve room deck, and the working deck, are 59 feet wide by 75 feet long, with a maximum height of 92 feet (from the north footing of the working deck to the roof deck of the terminal room). The at-grade deck of the structure is rectangular in shape, measuring approximately 44 feet wide by 38 feet deep. A small rectangular opening on this deck provides access to rooms below grade that were control and terminal rooms. Steel posts around the edge are all that remain of the original railings. On the eastern and western sides of this section of the test stand base are U-shaped cells measuring approximately 25 by 11 feet and approximately 50 feet high. The walls of the terminal room structure are the base of the U and have two parallel steel anchor bolts running vertically from the base of the stand to the terminal roof deck. The 20-foot-wide- by 15-foot-long valve room deck is located in the southeastern corner of the terminal roof deck and has a small opening with a wall-mounted steel ladder leading to the valve room below. Immediately north of the terminal roof deck, and 15 feet lower, is the irregularly shaped working deck. This deck is 60 feet wide at the juncture with the terminal room structure, 36 feet wide at the center, and 45 feet wide at the northern edge. The overall length of the deck, from the terminal room to the northern edge, is 29 feet.

The working deck is 42 feet above grade at the juncture with the terminal room and 75 feet above grade at the northern edge. This deck has six octagonally shaped openings to the structure below arranged in two rows of three. The test stands appear to be in fair condition, with standing water pooling in the rooms beneath the decks, spalling concrete in places, and general lack of maintenance. The superstructure of the building is entirely missing. It was removed during the late 1960s or early 1970s.

Bldg. 8649, Test Stand 1-4. Bldg. 8649 is a small test stand situated on the edge of Leuhman Ridge, on the southern side of Test Area 1-115's upper driveway. The building is two stories, with one level above the driveway grade (CA-236-I-4). The grade slopes dramatically from the driveway, leaving the bottom level predominantly exposed. Poured concrete steps on the eastern side of the building lead from the driveway to a door at the lower level (CA-236-I-6). The building is of poured concrete construction and consists of a series of cube forms arranged in an L plan (CA-236-I-3, CA-236-I-5, CA-236-I-7). The walls are sheer from the flat roof to the grade, except on the southern facade, where the western half of the upper story projects over the lower story by approximately 2 feet (CA-236-I-1). This projecting bay has two rows of evenly spaced holes pierced through the wall that originally housed the piping conduits for the fuels and oxidizers. One row is located approximately 1.5 feet from the roofline, and the other is in the eave of the projecting bay. At the base of the bottom story, below the projecting bay, is another row of pipe holes (CA-236-I-2). Fenestration on the test stand is minimal and consists of five rectangular openings on the upper level of the eastern facade and a wide steel door on the lower level of the eastern facade, a steel top-hung sliding door on the northern facade, and a steel strap-hinged door on the western facade. On the northern and western facades, there are rust marks and bolt holes, indicating that features have been removed that originally served to mount the test vehicle to the stand. Overall, the test stand is in poor condition. Despite the removal of some features associated with loading the test vehicles, the stand retains sufficient integrity to convey its significance as an early liquid engine rocket test stand.

Bldg. 8641, Test Stand 1-5. The existing structural base of Test Stand 1-5 (including the terminal roof deck, the valve room deck, and the working deck) measures 59 feet wide by 75 feet long (CA-236-K-3 through CA-236-K-6). The maximum height of the building (from the north footing of the working deck to the roof deck of the terminal room) is 92 feet. The ground-level terminal roof deck of the structure is rectangular, measuring approximately 44 feet wide by 38 feet deep (CA-236-K-1). A small rectangular opening on this deck provides access to the control and terminal rooms, which were below grade. Steel posts around the edge of this deck are all that remain of the original railings.

On the eastern and western sides of this section of the test stand base are U-shaped cells measuring approximately 25 by 11 feet and approximately 50 feet high (CA-236-K-2). The walls of the terminal room structure are the base of the U and have two parallel steel anchor bolts running vertically from the base of the stand to the terminal roof deck.

The 20-foot-wide- by 15-foot-long valve room deck is located in the southeastern corner of the terminal roof deck and has a small opening with a wall-mounted steel ladder leading to the valve room below. Immediately north of the terminal roof deck, and 15 feet lower, is the irregularly shaped working deck. This deck is 60 feet wide at the juncture with the terminal room structure, 36 feet wide at the center, and 45 feet wide at the northern edge. The overall length of the deck, from the terminal room to the northern edge, is 29 feet.

The working deck is 42 feet above grade at the juncture with the terminal room and 75 feet above grade at the northern edge. This deck has six octagonally shaped openings to the structure below arranged in two rows of three. The test stands appear to be in fair condition, with standing water pooling in the rooms beneath the decks, spalling concrete in places, and general lack of maintenance. The superstructure of the building is entirely missing. It was removed during the late 1960s or early 1970s.

Bldg. 8641, Test Stand 1-5, served a central technical function in the test area. Activated in October 1952 for Aerojet's RATO system, Test Stand 1-5 served as the area control building and was the first test stand activated at the Leuhman Ridge facility. Early tests of the RATO system reflect the AFRL's early association with the AFFTC, whereas later tests of the Atlas, Thor, Titan, and Bomarc programs illustrate AFRL's exceptionally important role in the advancement of the U.S. Cold War race for technological superiority.

Bldg. 8642. Bldg. 8642 is one story in height and has a rectangular plan (CA-236-L-1 through CA-236-L-3). It has a steel frame structure set on a concrete pad. The overall dimensions of the building are 40 feet by 60 feet. The 12-foot-high walls and the medium slope gable roof are covered with corrugated metal. Fenestration includes a single, top-hung sliding door measuring 10 feet wide by 12 feet high on the gable end facing the test stand and another on the side facing the driveway. Steel frame and sash 12-light windows are arranged in ribbon rows 16 feet wide, with three rows on the long, doorless facade, two rows on the doorless gable end, two rows flanking the door on the driveway facade, and two pairs of 12-light windows flanking the door on the remaining gable end. The interior of the building includes a general work area and a row of four small rooms (CA-236-L-4 through CA-236-L-6). The work area is a large, open space with exposed steel frame rafters. The rooms are walled off in the 15 feet farthest from the test stand entry. This row of rooms serves as the lavatory, locker room, office, and tool crib. The building appears to be in fair condition attributable primarily to minor deterioration over time and lack of maintenance.

Bldg. 8663. Bldg. 8663 is a standard Butler building (CA-236-M-1 through CA-236-M-4). The steel-framed rectangular building and the medium sloped gable roof are covered with seamed metal siding. The northeastern facade serves as the main entry, with a top-hung sliding door that opens from the south toward the middle and two six-over-three steel awning windows in the northern end of the facade. The southeastern facade consists of two single six-light steel awning windows; the southwestern facade consists of two six-light steel awning windows; and the northwestern facade consists of two six-light steel awning windows, one on each side of a hollow steel entry door. At the northern end of this facade, a poured concrete addition intersects with the wall. This one-story rectangular structure encroaches approximately 3 feet into the original building and extends perpendicularly approximately 15 feet to the northwest. The roof supports several ventilators and HVAC stacks and units. Much of the original helium compression units and controls remains intact inside the building (CA-236-M-5 through CA-236-M-8). The overall condition of the building is fair, with signs of failing metal around some windows and around the roof.

Bldg. 8668. Bldg. 8668 is a one-story, semisubterranean building with a rectangular plan. It is constructed of reinforced, poured concrete and has a flat roof. The entry to the building is recessed into the ridge with concrete retaining walls leading to the entry door (CA-236-N-2, CA-236-N-3). The northern retaining wall also serves as a wall for an enclosed walkway that leads from Bldg. 8668 to Test Stand 1-3 (CA-236-N-9). Fenestration is minimal, consisting of two square, recessed bullet-glass windows on the eastern and western facades for viewing the test stands (CA-236-N-3, CA-236-N-4, CA-236-N-7). The roof houses an escape hatch from the control room below and several periscopes for viewing the test stands (CA-236-N-5, CA-236-N-6, CA-236-N-8). The interior consists of the control room, an instrumentation room, and an observation hall (CA-236-N-10 through CA-236-N-15).

Bldg. 8680. Bldg. 8680 is a poured concrete, one-story rectangular building with a small corrugated metal addition to the northern facade (CA-236-G-1, CA-236-G-2). The building has a flat, builtup roof with metal coping and eaves approximately 6 inches deep. The only fenestration consists of a steel entry door on the northern facade and four recessed openings with steel fixed louvers on the eastern facade.

Test Area 1-120

In November 1954, final drawings and specifications were prepared for Test Stand 1-A by the Ralph M. Parsons Company (CA-236-R-26, CA-236-R-27). Drawings and specifications had to reflect the latest in design techniques, which made Test Stand 1-A the foremost of the new rocket test facilities. It was designed for 1,000,000-pound thrust capacity with a very large safety factor and was the first test stand on which a complete Atlas missile system could be tested (Eppley 1961).

On March 31, 1955, the construction contract for Test Stand 1-A was awarded to G. A. Fuller Construction Company by the Corps. Groundbreaking was in May 1955, and construction of Test Stand 1-A was completed in November 1956.

The control room building (Bldg. 8783) was designed to protect test support personnel from mishaps on the rocket test stands. It served as a mission control room, office space, and rocket firing viewing area complete with window glass thick enough to withstand explosions on the test stands. A tunnel system linked the control room building with Test Stand 1-A and later with Test Stands 2-A and 1-B (CA-236-14, CA-236-15). The mission control room originally contained strip charts, oscillographs, and high-frequency FM tape-recording systems, which allowed the engineers to analyze the test data. The room had more than 500 data-collecting channels with 300 recorders. The actual rocket firing was controlled by mechanical clock timers and sequencers.

In addition to the control room, personnel could view firings on the test stand from one of the observation and camera buildings positioned around the test stand (CA-236-D-2, CA-236-D-4, CA-236-D-6, CA-236-D-7, CA-236-D-8). These bunkers were positioned around the sides and front of the test stand and often were built into the mesa for added protection (CA-236-D-3, CA-236-D-5, CA-236-D-9, CA-236-D-10, CA-236-D-11). The form of the bunkers was consistently a poured concrete box with an entry door at the rear and narrow, horizontal viewing windows on the front that were shaded with a metal awning (CA-236-D-1, CA-236-D-12).

The Convair Division of the General Dynamics Corporation had practically completed tests on the Atlas missile at Test Stand 1-A when the missile malfunctioned and exploded during a test on March 27, 1959. The test stand was damaged to such an extent that is was impractical to rebuild it for the two tests remaining to complete the Atlas program. Test Stand 1-A was transferred to Rocketdyne under a use agreement signed on July 28, 1959, by Air Force and Rocketdyne representatives. Under the use agreement, Rocketdyne would modify Test Stand 1-A at a cost of $3 million to test the F-1 engine. This figure would include not only the modification work, but upgrading of the test equipment. Modified Test Stand 1-A was the cornerstone of what was to become the NASA Static Rocket Engine Test Complex, which would eventually include Test

Stand 1-B, Test Stand 2-A, and the control room. The control room for Test Stand 1-A also was modified.

A target date of September 1960 was set for completing modifications to Test Stand 1-A. At that time, the test stand would be fully operational. The test stand reconfiguration activity in 1959 through 1960 consisted of the following modifications:

- The Atlas tower was removed.
- A new thrust structure with a load measurement system was installed.
- The run tank support structure was fabricated.
- Propellant ready storage and run tanks and an engine feed system for LO_2 and RP-1 were installed.
- The flame deflector system was enlarged and the test stand fire control system expanded (CA-236-Q-1 through CA-236-Q-4).
- New instrumentation and control systems were added and the data acquisition system expanded.

These modifications to Test Stand 1-A were completed in September 1960. Detailed plans and drawings for the test stand in that configuration exist and are filed in the Phillips Laboratory Fabrication Branch.

The test stand was converted from the Atlas missile configuration to the present configuration for static testing of the E-1 and F-1 engines. Modifications were made to upgrade the test stand to a 1,600,000-pound thrust capability. Development of the E-1 and F-1 engines reflected a shift in priorities for the test area from Cold War ICBMs to manned space flight. Approximately 700 engine firings were accomplished from activation in 1960 until research and development were completed in 1969.

Bldg. 8765, Test Stand 1-A. Bldg. 8765 is the substructure of Test Stand 1-A (CA-236-R-1). This massive structure is 70 feet wide and 150 feet high at the northern edge and 50 feet wide and 110 feet high at the southern edge, with an overall length of 203 feet from the northern edge to the southern edge. The entire structure is constructed of reinforced concrete. The top deck of the test stand is level with the road in the test area; thus, the structure is primarily subterranean or cantilevered from the northern ridge face. The overall form of the structure is a two-level rectangle between the northern and southern structural piers and a braced cantilevered deck extending from the northern structural pier. A poured concrete, U-shaped deflector pit descends north from the north structural pier at an approximately 60-degree angle from 45 feet below the topdeck (CA-236-R-4). The top deck has a hole in the northern end measuring approximately 60 feet wide by 40 feet long. The superstructure above the top deck holds the test vehicle above this opening, directing the blast of the rocket down to the flame deflector pit (CA-236-R-2, CA-236-R-3, CA-236-R-5).

The superstructure that holds the test vehicle, the fuel, and the oxidizer has been modified over the years to meet the needs of new testing programs. The current structure is two rectangular, steel, open frames (CA-236-R-6 through CA-236-R-19). The southern frame is of lighter steel and supports the fuel and oxidizer tanks on top. The northern frame is of heavier steel and supports the test vehicle in the center of the lower third of the structure. There are two levels of work space below the top deck of Test Stand 1-A in the southern 149 feet of the test stand, referred to as Bldg.8783 (CA-236-O-1 through CA-236-O-12). The test stand appears to be in good condition.

Bldg. 8762. Bldg. 8762 is the control room for Test Stands 1-A, 1-B, and 2-A (CA-236-E-1, CA-236-E-5). It is a poured concrete building with complex massing and an irregular plan (CA-236-E-6, CA-236-E-7). Most of the building is subterranean, and the overall dimensions are 50 feet by 164 feet. The length of the building is divided into seven structural bays. The first, and northernmost, bay is three stories high, two of which are subterranean. The next three bays are one story high and are subterranean at the first basement level. The next three bays are two stories high, one above ground and one at the first basement level. The last bay is one story high at the first basement level. The second basement level at the northern end is 12 feet high and houses the terminal vault and provides pedestrian access to the underground tunnels that lead to the terminal rooms beneath Test Stands 1-A and 1-B (CA-236-E-3). These tunnels also house the conduits and cable trays that once carried the extensive wiring from the control room to the terminal rooms beneath the test stands (CA-236-E-8). The first basement level is 15 feet high and serves as the control room and administrative office spaces (CA-236-E-2, CA-236-E-4). The top level at the north end is 10 feet high and serves as the observation post. The northern wall at this level has five narrow viewing windows facing Test Stand 1-A. This building appears to be in excellent condition.

Test Area 1-125

Test Area 1-125 is located at the northeastern end of Leuhman Ridge, approximately 1 mile from the main administrative complex. Test Area 1-125 was constructed for the production testing of the Saturn V first-stage F-1 engine. Construction was completed in 1964 and consisted of three large test stands capable of withstanding up to 2 million pounds of thrust, a control building, and associated support structures (CA-236-13).

This test area consists of three identical high-thrust-capacity test stands and their associated buildup buildings and observation bunkers and a central control building. Bldg. 8844 is the control center, located at the center of the southern edge of the area. Bldg. 8810/Test Stand 1-C and Bldg. 8812 are located approximately 500 feet northwest of the control center. Bldg. 8820/ Test Stand 1-D and Bldg. 8826 are located approximately 1,000 feet north of the control center. Bldg. 8832/Test Stand 1-E and Bldg. 8840 are located approximately 750 feet east of the control center. Eight small observation buildings (Bldgs. 8804, 8814, 8816, 8822, 8824, 8832, 8834, and 8836) are positioned throughout the test area to afford views of all the test stands.

Each of the observation bunkers, except Bldg. 8804, were built to an identical plan (CA-236-H-4). Test Stands 1-E and 1-D each have three observation bunkers, and Test Stand 1-C has two. The observation bunker is a small rectangular structure constructed of reinforced concrete. The structure consists of a front wall with two viewing windows, a rear wall with an entry door, two side walls, a flat roof, and a poured concrete finished floor. The walls and foundation are a continuous pour, with 2 feet, 2 inches below grade and 9 feet, 4 inches above grade. Six steel anchor ties extend from 2 feet, 8 inches high in the front and back walls down to a depth of 9 feet. The roof is a 1-foot, 3-inch concrete slab, making the total exterior above-grade height 10 feet, 7 inches and the interior height 8 feet, 4 inches. Plan dimensions are 14 feet, 6 inches by 10 feet, 3 inches on the exterior and 12 feet by 9 feet on the interior. The center lines of the two windows on the front facade are 4 feet, 9 inches from the exterior edges, with 5 feet between center lines. The windows are approximately 4 feet above the finished floor and measure approximately 2 feet wide by 1 foot, 6 inches high on the exterior. The window opening telescopes down to approximately 1 foot wide by 9 inches high. The opening is covered with bullet glass to resist blasts from test firings. A horizontal, louvered metal sun shade extends perpendicularly from 6 feet, 10 inches above grade. The rear facade of the bunker consists of a metal entry door in the right third of the facade. The door measures approximately 2 feet, 6 inches wide by 7 feet high. A cantilevered steel shelf is attached to the left third of the rear facade at 3 feet, 6 inches above grade. The shelf is 2 feet, 6 inches deep and 2 feet, 10½ inches wide.

Bldg. 8804. Bldg. 8804 is an observation bunker associated with Test Stand 1-D. This is the only bunker that deviates from the standard plan. The deviation is that the sun shade is positioned 7 feet, 6 inches above grade rather than the standard 6 feet, 10 inches. This bunker is the northernmost bunker and sits at a lower elevation than the deck of the test stand. It faces southwest, toward the front of the test stand.

Bldg. 8814. Bldg. 8814, the southernmost observation bunker for Test Stand 1-D, sits on the driveway leading to the test stand (CA-236-H-1 through CA-236-H-3). It faces northwest, toward the deck of the test stand.

Bldg. 8816. Bldg. 8816, the northernmost observation bunker for Test Stand 1-C, sits west of Bldg. 8814 on the downward slope of the opposite side of the driveway. It faces southwest, toward the northern side of Test Stand 1-C.

Bldg. 8822. Bldg. 8822 is the easternmost observation bunker for Test Stand 1-D. It sits above the test stand, facing the northeastern side and deck of the test stand.

Bldg. 8824. Bldg. 8824 is the southernmost observation bunker for Test Stand 1-C. It sits at a slightly lower elevation than the deck of the test stand and is entered via a dirt road that winds along the hill below the water tanks. This bunker faces northeast, toward the front and south sides of the test stand.

PART V. SOURCES OF INFORMATION

Interviews

Five oral history interviews were conducted with individuals who worked at the AFRL, Edwards AFB, California: Robert Corley, Robert Geisler, William Lawrence, Lee Meyer, and Robert Wiswell. The following are summaries of these interviews. The interviews were conducted according to the guidelines established in the Technical Report: Legacy of Pancho Barnes Oral History Program (Terrero 1994). The audiotapes and transcriptions of the interviews are archived at the Edwards AFB Environmental Management Office curation center. Access to the interview materials is available for management and research purposes through the Base Historic Preservation Officer.

On March 19, 1998, an audiotaped oral history interview was conducted with **Robert Corley** at his office at the AFRL. In 1958, Mr. Corley came to the AFRL, where he worked as a chemist on liquid and solid propellants. Originally a lieutenant, Mr. Corley returned to the lab after a 5-year hiatus (1961–1966) as a civilian and worked primarily in solid propellants. He managed projects and continues his employment at the AFRL as a senior scientist, overseeing the technical content of programs. During his interview, Mr. Corley described the processes of project management for in-house and contracted work at the AFRL. Having worked with both solid and liquid propellants, he was able to discuss the differences between the fuels and the advantages and disadvantages of each. He also compared the atmosphere at the AFRL in the 1950s and 1960s to that in the 1990s. Mr. Corley shared information regarding the AFRL's role in the field of rocketry and propulsion, comparing its role with that of the other branches of the armed services. Finally, he shed light on important programs conducted at the AFRL, including the Ballistic Test, Evaluation, and Scaling (BATES) program and fuel development programs.

On March 18, 1998, an audiotaped oral history interview was conducted with **Robert Geisler** at his home office in Tehachapi, California. Mr. Geisler is a chemical engineer who worked at the AFRL from 1959 to 1990. He was one of the scientists who moved to Edwards AFB from Wright-Patterson AFB. During his time at the AFRL, he was involved in programs at several test areas. He worked as a detective of sorts, finding the causes of failed tests and vehicles and researching foreign rocket programs to keep the Air Force apprised of the potential capabilities of other nations. During his interview, Mr. Geisler shared recollections of the early days of the AFRL and information regarding physical changes made to test areas over the years. He also shared insights regarding the political climate in the Air Force and the propulsion industry. Mr. Geisler provided copies of documents detailing the history of the AFRL and solid propellant research at the AFRL. His knowledge of events and programs at the AFRL and the inner workings of the Defense Department was important in helping the authors understand the physical, technological, and political development of the AFRL.

On March 19, 1998, an audiotaped oral history interview was conducted with **William Lawrence** at his office in City Hall in Lancaster, California. Mr. Lawrence is a mechanical engineer with an M.A. in business. In 1955, he came to the AFRL, where he was involved in providing mechanical support and developing facility design and layout criteria. Since his retirement in 1981, Mr. Lawrence has been working with contractors and has remained involved with the AFRL. During his interview, he shared his knowledge regarding the history and design of the facilities at the AFRL, as well as some of the programs carried out there over the years. He conducted a verbal tour through the history of the AFRL, describing the initial purposes of, further additions and modifications to, testing programs of, and present uses of, the individual test areas. In addition, he provided insights regarding the overall context of the research and development that have taken place at the AFRL and other propulsion research facilities. Mr. Lawrence's knowledge of the industry and experience at the AFRL make him an important source of information. His interview provided the authors with a coherent, overarching view of the AFRL and its place in the larger contexts of propulsion research and development, the arms race, and the space race.

On March 16, 1998, an audiotaped oral history interview was conducted with **Lee Meyer** at his home office in Lancaster, California. Mr. Meyer, a mechanical engineer, was assigned to the AFRL in 1963 and worked primarily in Test Areas 1-32 and 1-46 until he retired in January 1998. In his interview, Mr. Meyer provided information on the early development of the laboratory, particularly the Mars Boulevard area, and insights into the relationships between the Air Force and NASA and contractors. In addition, he offered comparisons of liquid and solid fuel research and insights regarding the relationships between the scientists in both areas. Mr. Meyer's interview helped the authors further understand the role, past and present, of the AFRL in the broader context of propulsion research.

On March 17, 1998, an audiotaped oral history interview was conducted with **Robert Wiswell** at his home in Lancaster, California. He began his career in rocket propulsion in 1958 at Wright-Patterson AFB in Ohio and was transferred to Edwards AFB in 1959. He worked primarily with liquid propellants, at the hydrodynamics laboratory (now Test Area 1-14) and the Space Propulsion Environmental Facility. Although he retired in 1991, Mr. Wiswell still works part time at the rocket lab. He was able to provide the interviewer with his impression of the laboratory on his arrival. He shared information regarding the beginnings of missile development and the ways in which the laboratory attempts to provide necessary technology for use in the future. Finally, Mr. Wiswell supplied the interviewer with a list of potential oral history candidates, many of whom transferred from Wright-Patterson AFB with him. His interview provided the researchers with an overall view of the changing uses of rocket technology and the changing climate of rocket propulsion research over the years.

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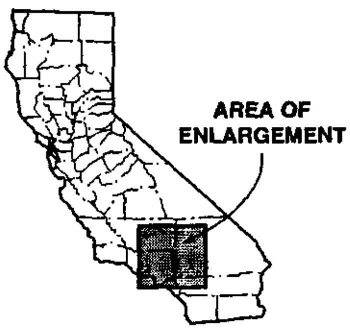
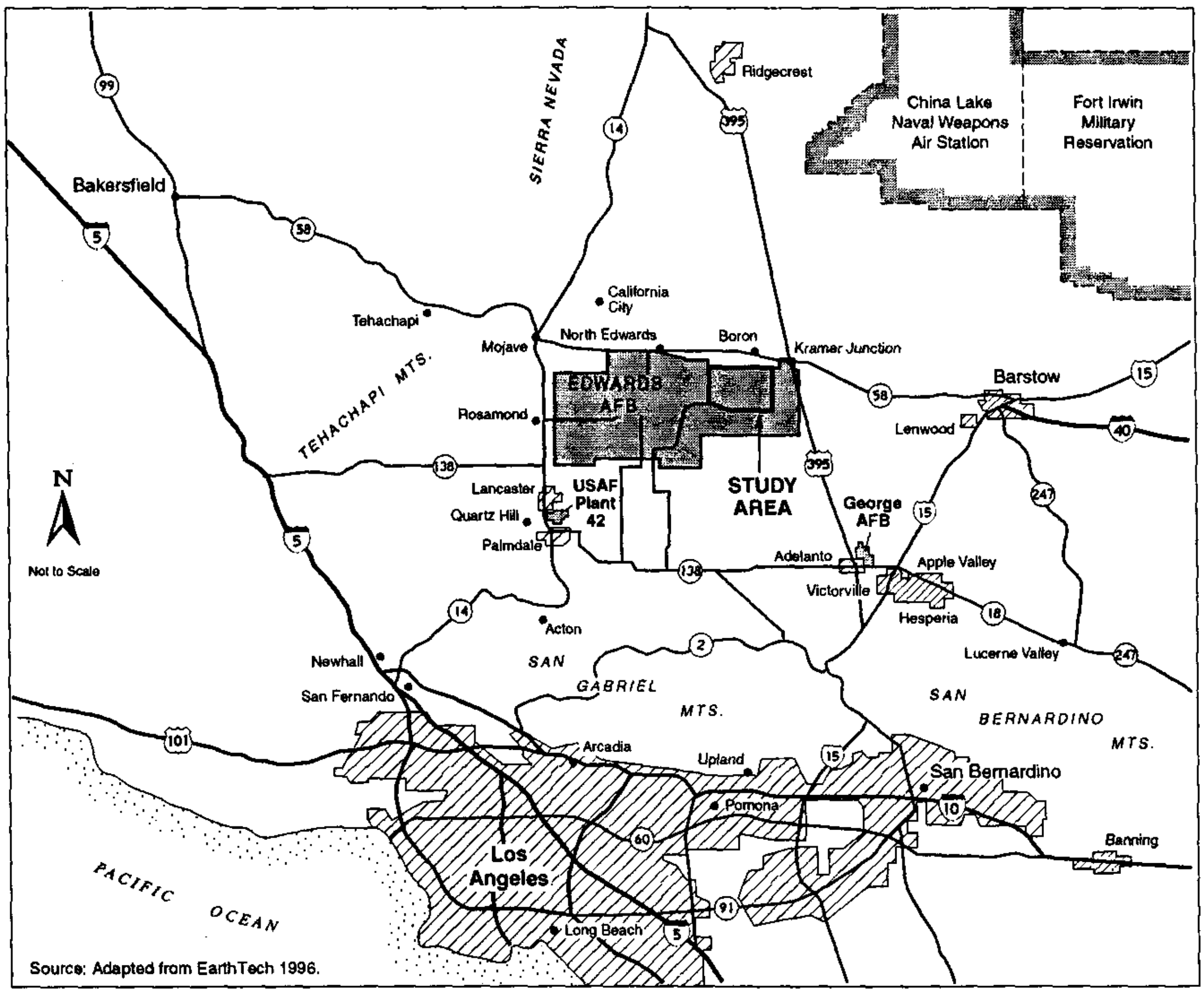
PART VI. PROJECT INFORMATION

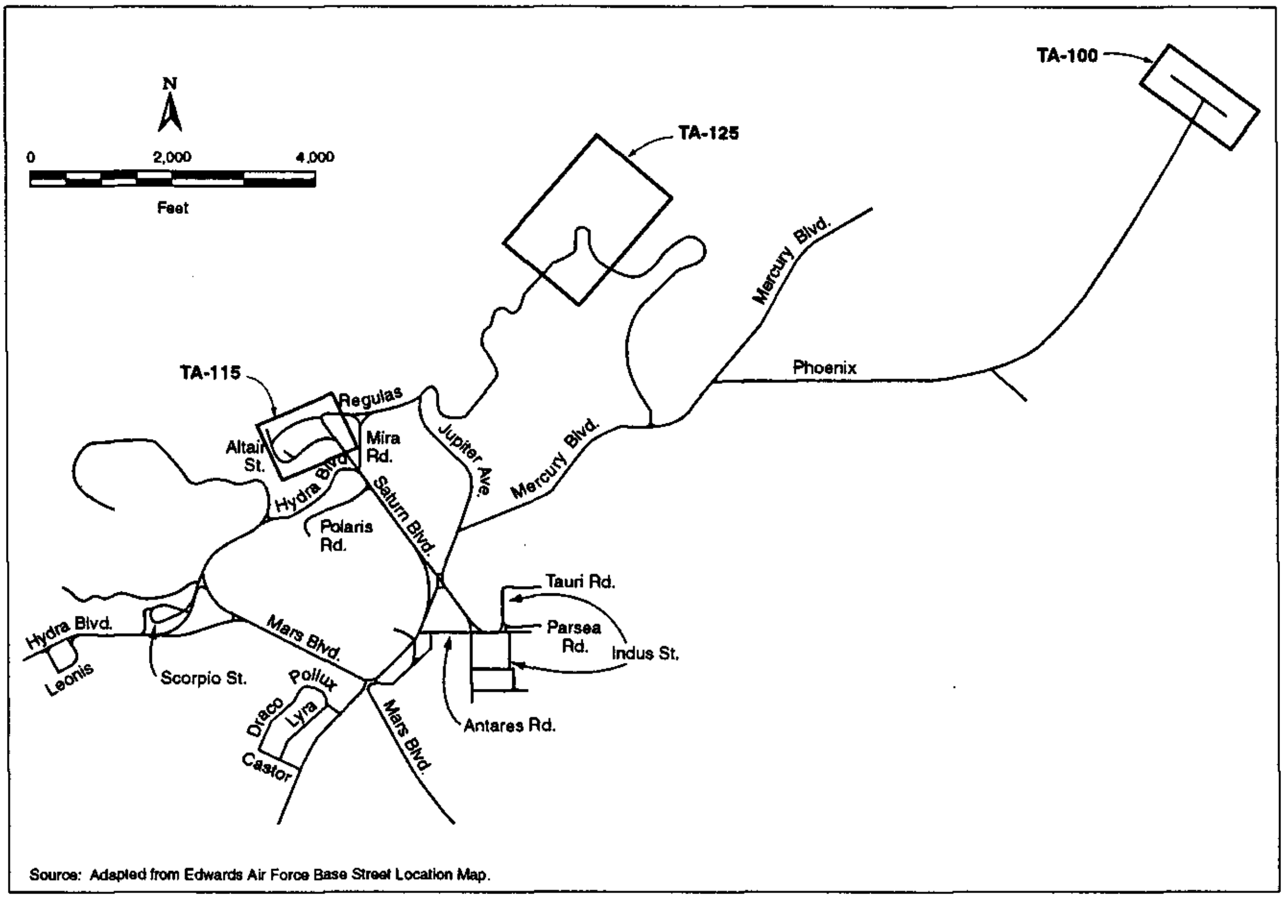
This report has been prepared to mitigate adverse effects caused by the demolition of 14 buildings at the Air Force Research Laboratory. The buildings to be demolished are associated with Test Areas 1-100, 1-115, 1-120, and 1-125. A previous study recommended these test areas as being eligible for listing in the National Register of Historic Places (NRHP) under Criterion A (and in the case of Test Area 1-100, Criterion C also) as historic districts and Criteria Consideration G as a property having achieved significance within the last 50 years. Because the documentation of all buildings in the eligible districts was outside the scope of this project, the documentation and photo index have been organized to allow for the addition of buildings and test areas over time.

This project was conducted under Contract DACW05-95-D-0003/ Task Order 071 and was overseen by the Edwards Air Force Base Historic Preservation Officer, Richard Norwood. The narrative portion of this document was prepared by Susan Lassell, Shahira Ashkar, Monte Kim, and Dana McGowan of Jones & Stokes Associates, Inc. (Sacramento, California). Photographic documentation was completed by David DeVries of Mesa Technical, Berkeley, California.

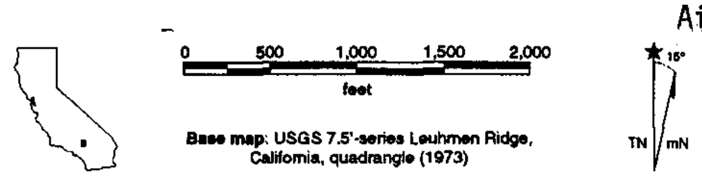


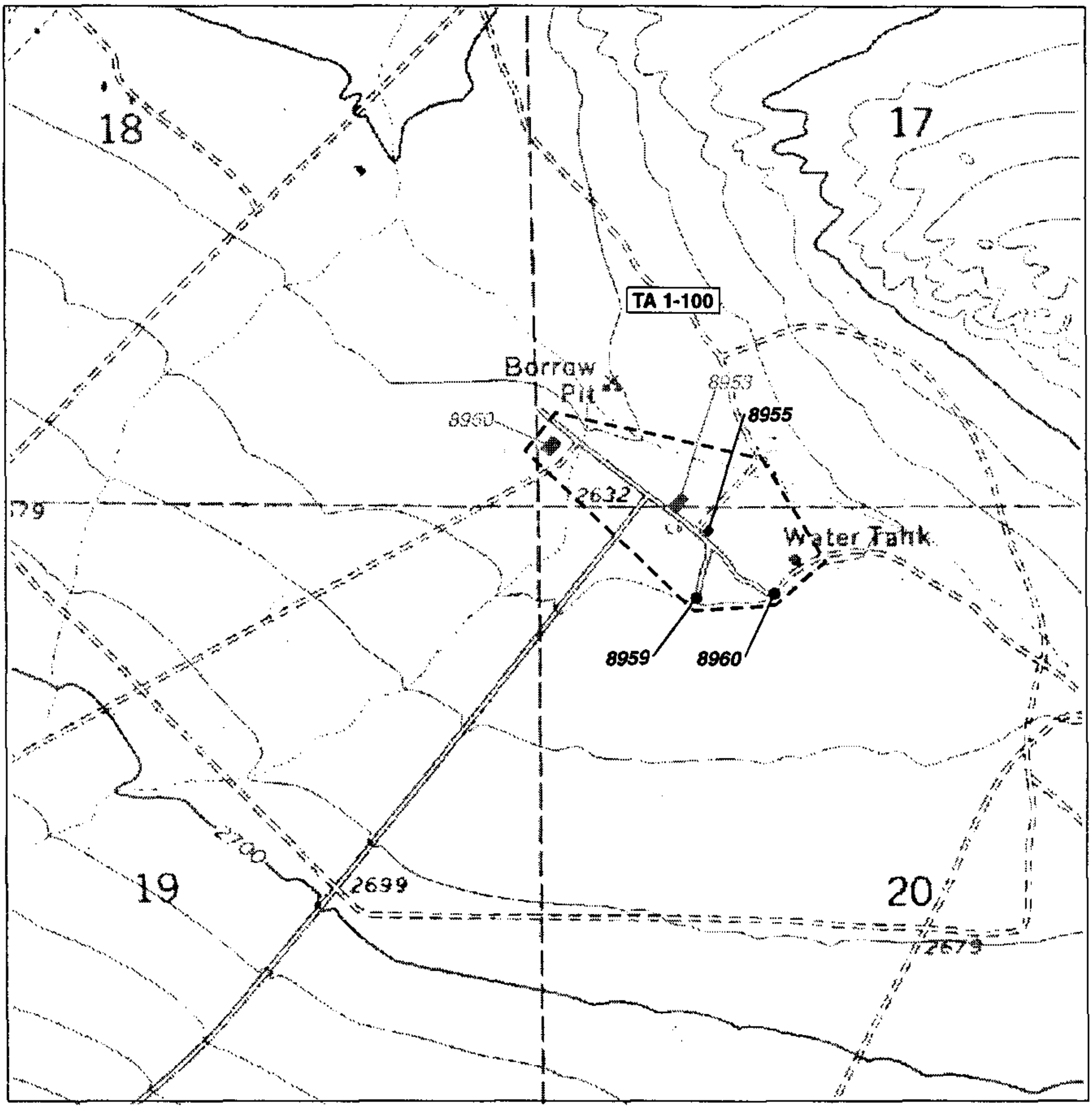


Project Vicinity Map, Edwards AFB, California



Affected Test Areas at the Air Force Research Laboratory





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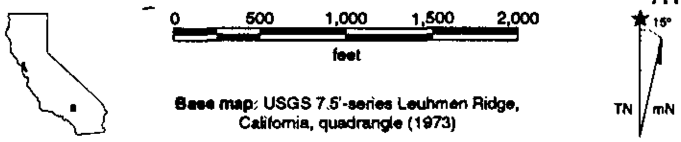

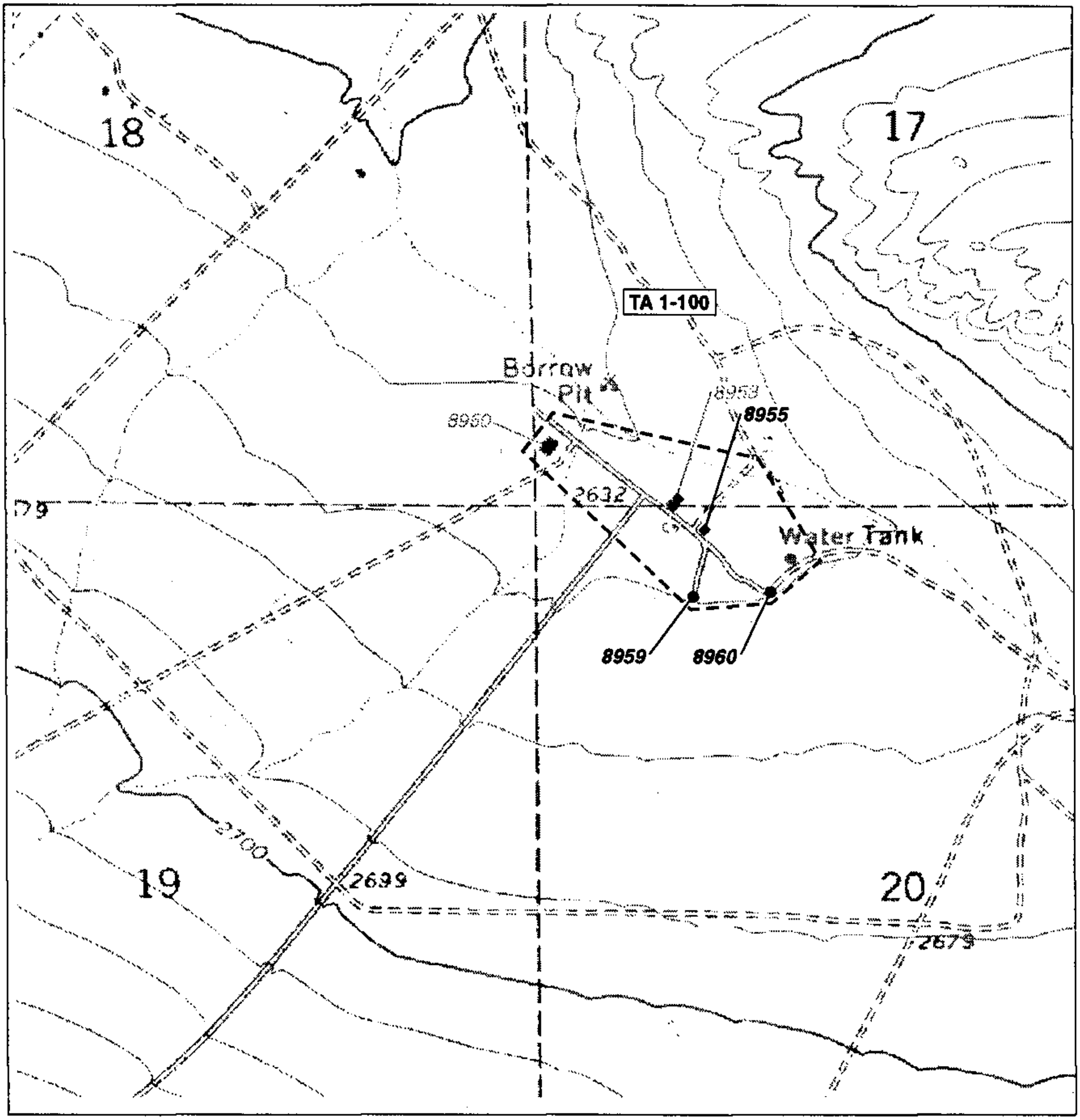

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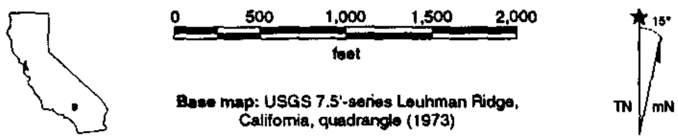

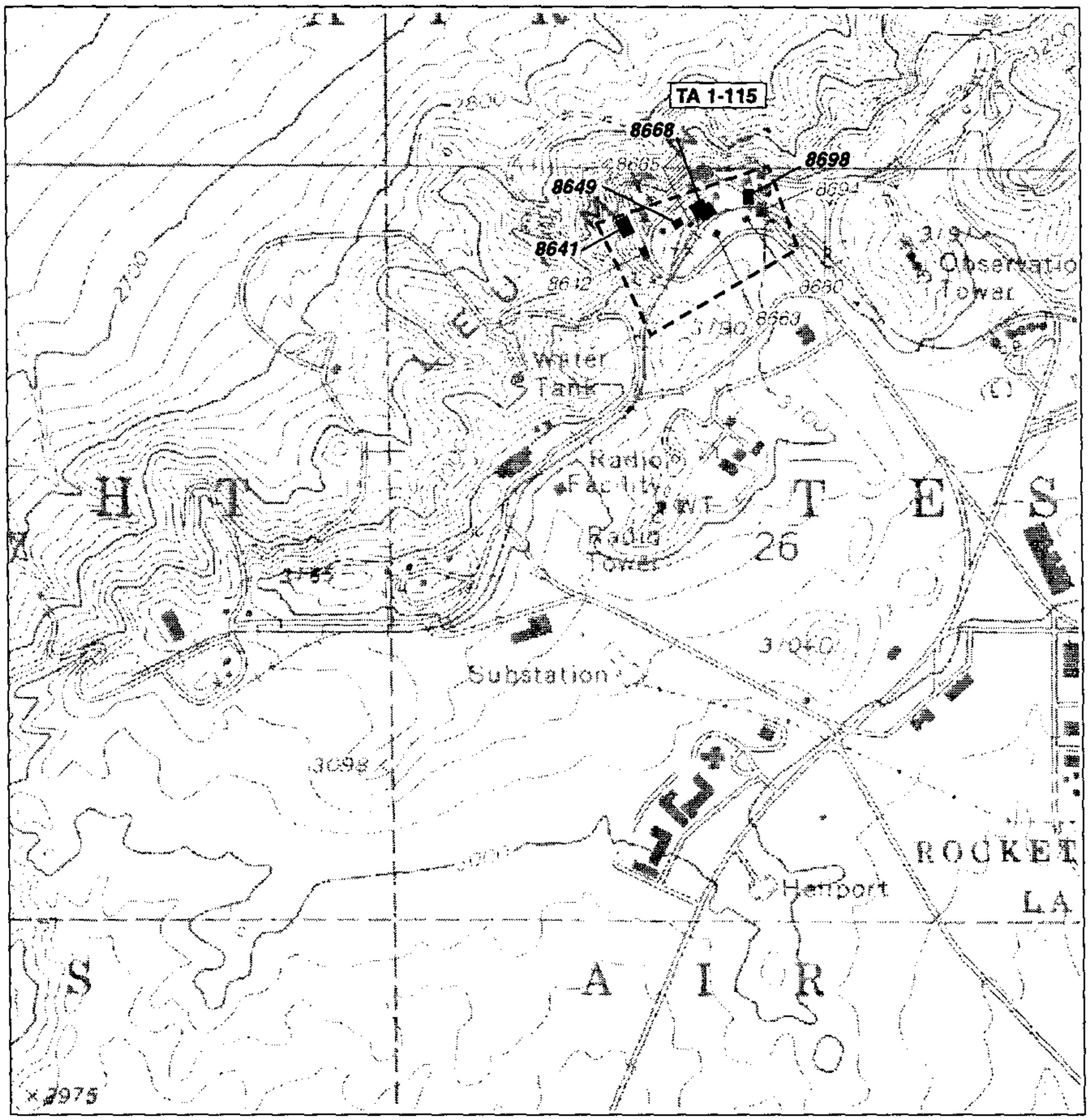

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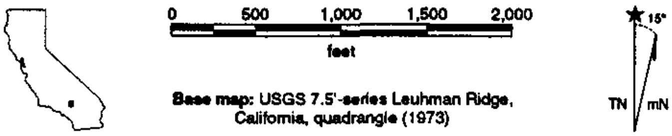

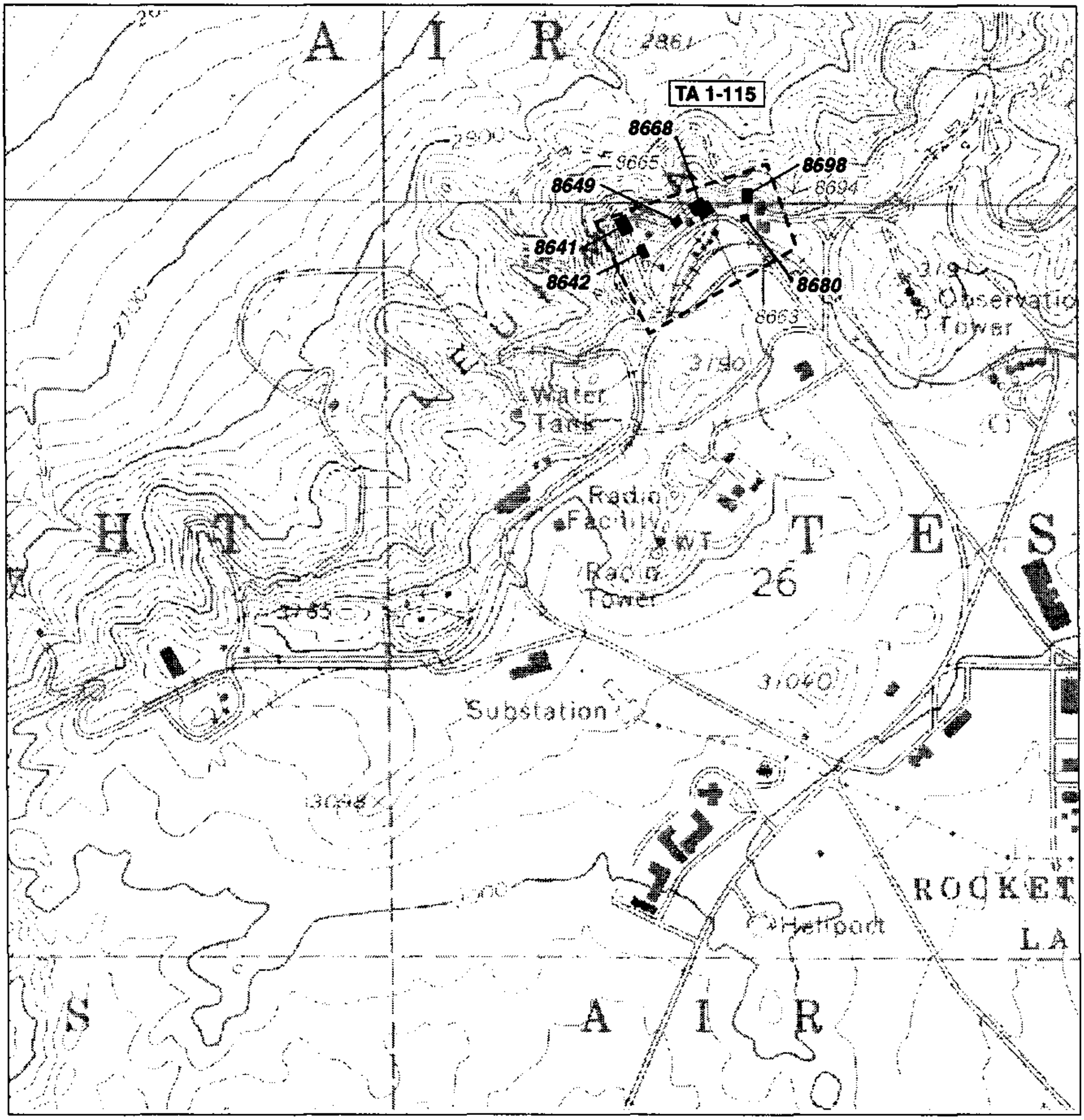

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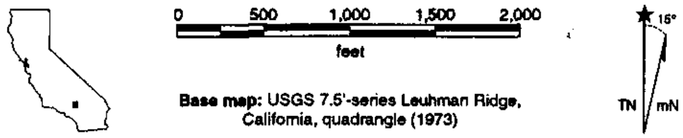

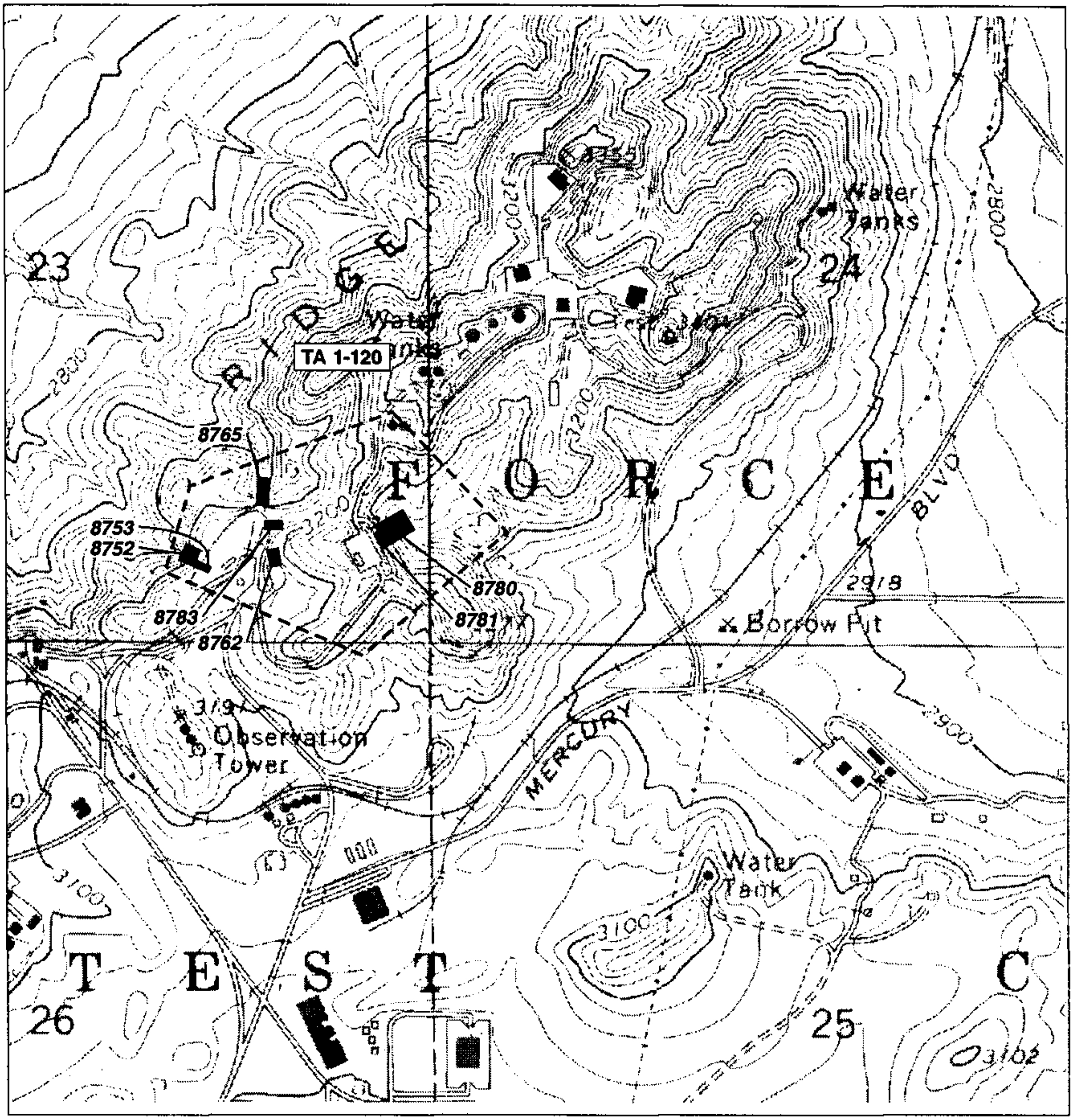

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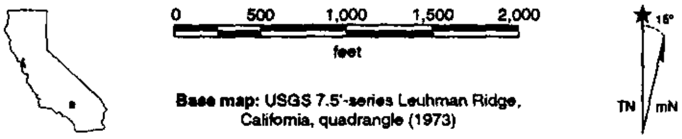

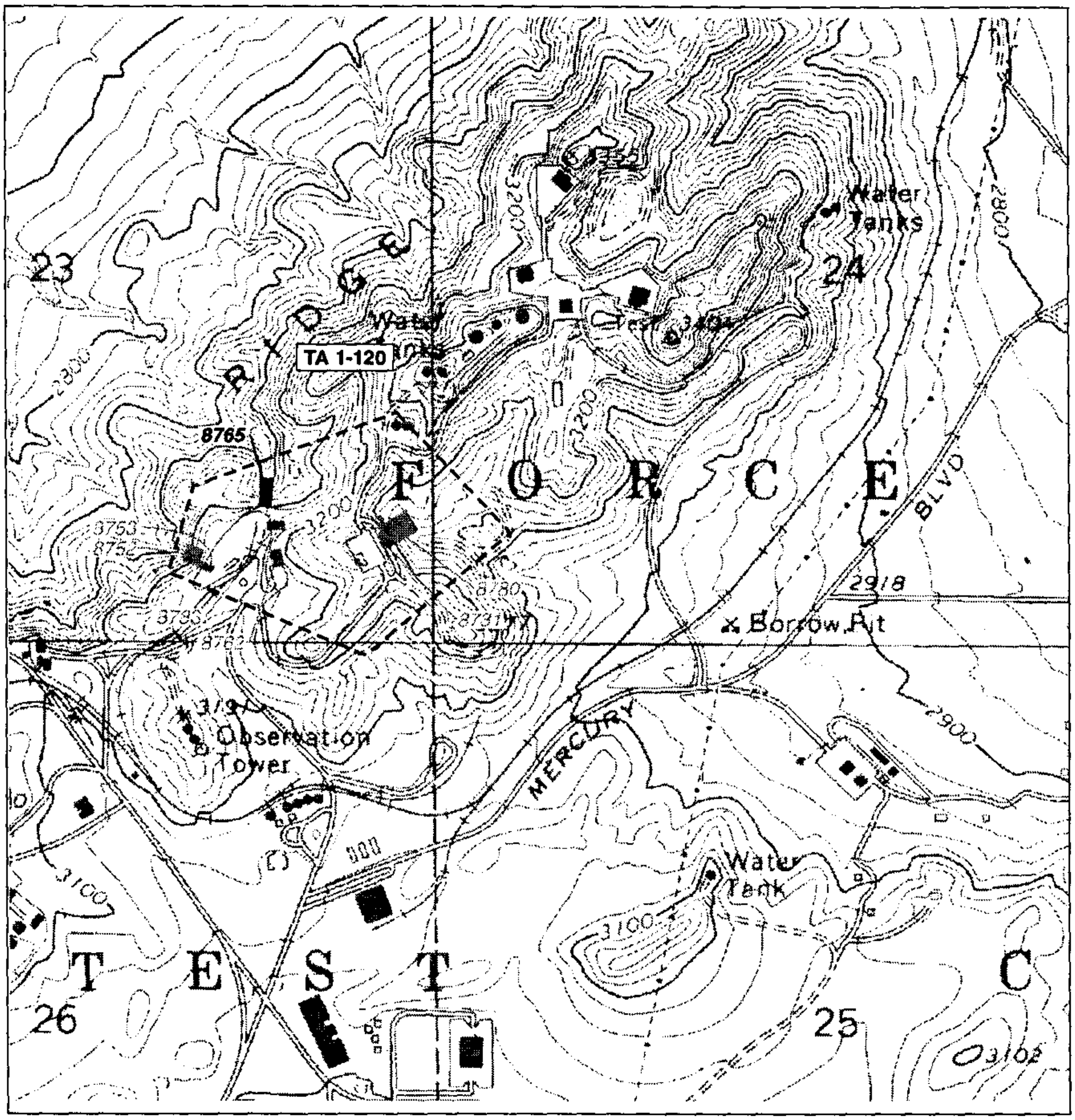

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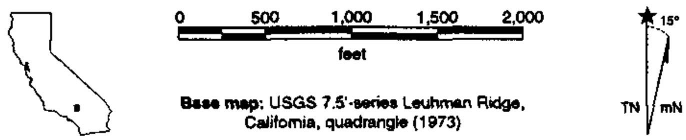

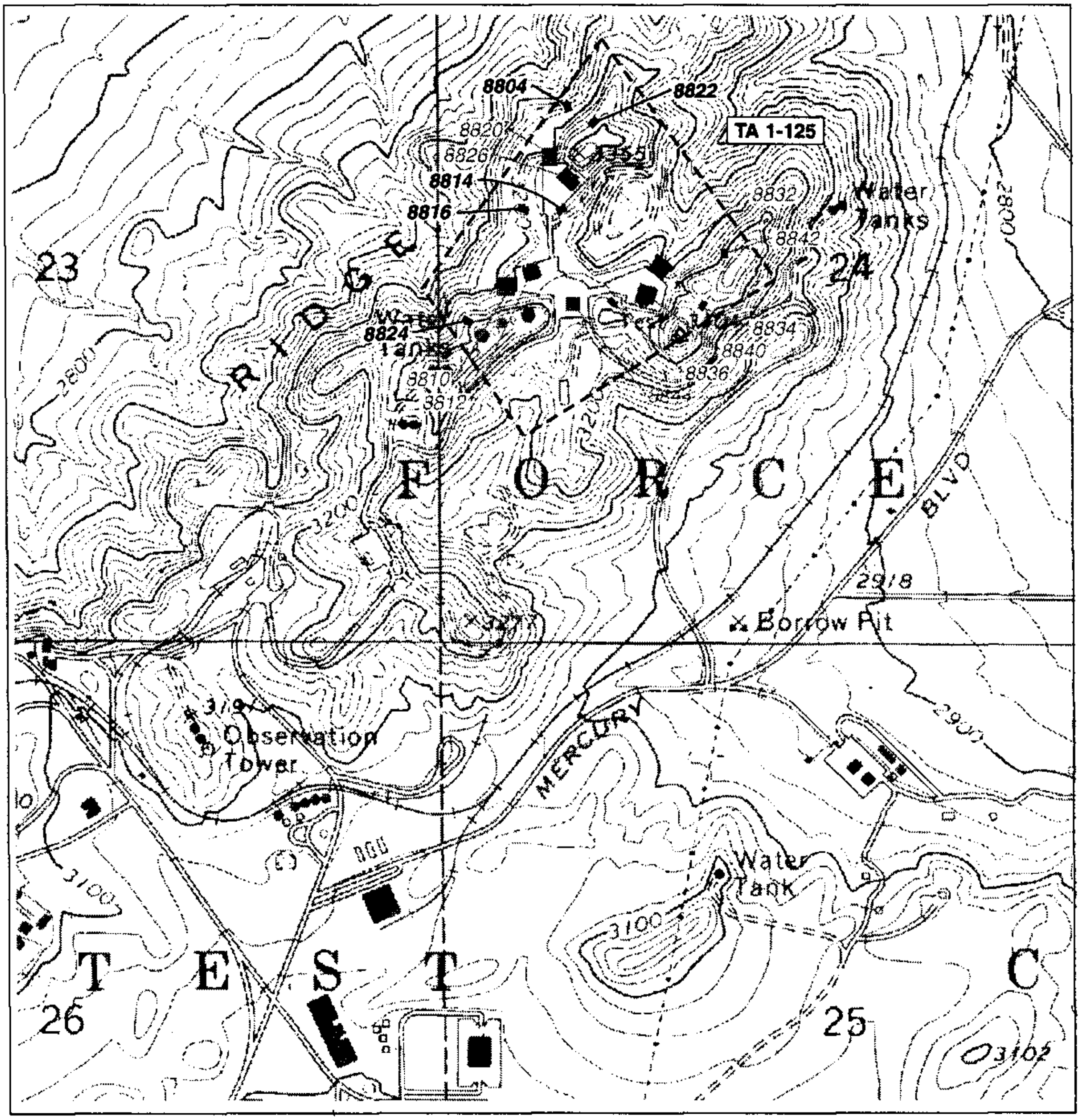

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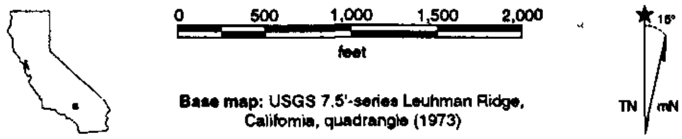

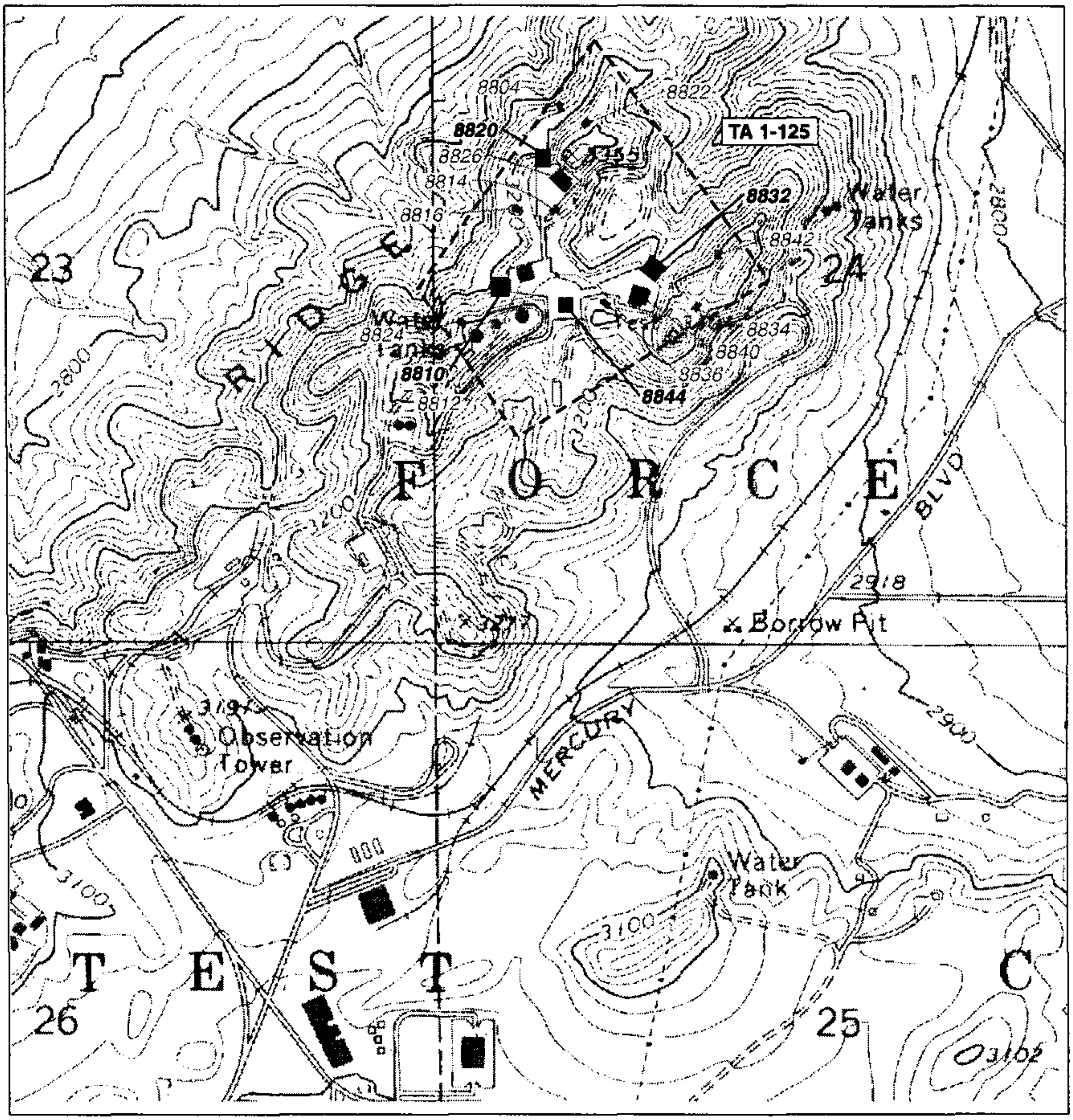

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